Department for
Energy Security
& Net Zero

The Home Energy Model: Future Homes Standard assessment

Using the Home Energy Model to demonstrate compliance with the Future Homes Standard

Closing date: 23:59 on 27 March 2024 (extended from 6 March)

December 2023

Any enquiries regarding this publication should be sent to us at: homeenergymodel@energysecurity.gov.uk

Executive Summary

This consultation presents the government's Home Energy Model: Future Homes Standard assessment, a methodology designed to assess compliance with the 2025 Future Homes Standard (FHS). The FHS will require new homes to be future proofed with low carbon heating and high levels of energy efficiency, through uplifts to the Building Regulations.

The Home Energy Model: FHS assessment builds on the government's new Home Energy Model, which will replace the existing Standard Assessment Procedure (SAP) for the energy rating of dwellings.

When assessing the energy performance of a new home, standardised assumptions need to be used for e.g. occupancy and occupant behaviour (what temperature the thermostat is set at, how much hot water is used etc.). This provides a consistent assessment process and ensures that all new homes are treated fairly. Other assumptions (e.g. the carbon intensity of electricity) are used to calculate the performance metrics that will determine a home's compliance with the FHS. This document sets out the proposed standardised assumptions for the Home Energy Model: FHS assessment, their justifications, and the work that has been done to validate the methodology.

Alongside this document, we have published a consultation tool, which gives stakeholders the opportunity to interact with the model and understand whether different dwelling designs are likely to comply with the proposed FHS. This tool has been developed for the purpose of the consultation and is not intended to be representative of the user experience when the model goes 'live'.

This consultation will be of interest across the built environment sector, and we look forward to engaging with stakeholders to facilitate feedback on the methodology.

Throughout the consultation period, we will be running a series of stakeholder engagement events. Please email homeenergymodel@energysecurity.gov.uk to find out more.

Contents

General information

Why we are consulting

The government is consulting on the Home Energy Model: Future Homes Standard assessment, which will be used to demonstrate new homes' compliance with the Future Homes Standard (FHS).

The Home Energy Model: FHS assessment will replace the government's Standard Assessment Procedure (SAP) for the energy rating of dwellings, version 10.2. SAP 10.2 is the current approved methodology to demonstrate that new homes in England comply with energy performance standards in the Building Regulations.

Uplifts to the Building Regulations will introduce the FHS for new homes in England from 2025.

We are publishing this consultation in order to:

- summarise the development and validation work undertaken to date; and
- facilitate feedback to enable further model development in advance of its introduction.

The Home Energy Model: FHS assessment will be implemented alongside the FHS in 2025. We are publishing this consultation while the Home Energy Model: FHS assessment is still at a formative stage to enable industry to participate in the ongoing development process.

Consultation details

Issued: 13/12/2023

Respond by: 23:59 on 27/03/2024

Enquiries to: homeenergymodel@energysecurity.gov.uk

Consultation reference: Home Energy Model: Future Homes Standard assessment

Audiences:

This consultation will be of interest to several different audiences such as:

- SAP/RdSAP assessors and assessor accreditation schemes
- Construction industry professionals
- Product manufacturers and suppliers
- Local authorities and other building control bodies
- Academics and consultants

Given the variety of audiences, we set out which parts of the consultation might be of particular interest to specific groups in Chapter 1.

Territorial extent:

The Future Homes Standard relates to Building Regulations for England only. Therefore, this consultation on the Home Energy Model: FHS assessment is for England only.

Historically, the Devolved Administrations have used an adapted version of SAP to demonstrate compliance with energy performance standards in their own building regulations. Therefore, this consultation will likely be of interest to stakeholders from all parts of the UK.

The Devolved Administrations have been kept informed during the development of this consultation and will each determine whether they will use an adapted version of the Home Energy Model: FHS assessment for their own devolved purposes in future.

How to respond

We strongly encourage responses via Citizen Space. Consultations receive a high-level of interest across many sectors. Using the online service greatly assists our analysis of the responses, enabling more efficient and effective consideration of the issues raised.

Respond online at: https://energygovuk.citizenspace.com/heat/home-energy-model-future-homes-standard

Or if you are unable to respond via Citizen Space:

Email to: homeenergymodel@energysecurity.gov.uk

Please do not send responses by post to the department.

When responding, please state whether you are responding as an individual or representing the views of an organisation.

Your response will be most useful if it is framed in direct response to the questions posed, though further comments and evidence are also welcome.

Confidentiality and data protection

Information you provide in response to this consultation, including personal information, may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000, the Data Protection Act 2018 and the Environmental Information Regulations 2004).

If you want the information that you provide to be treated as confidential please tell us, but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws. See our Privacy notice relating to consultation responses and Personal information charter for more information.

We intend to share responses to this consultation, including personal data, with our third-party contractors (the Building Research Establishment Limited and Etude) for the purposes of analysis of consultation responses and further development of the Home Energy Model. We also intend to share anonymised responses with the Devolved Administrations for their use in policy development work.

We will summarise all responses and publish this summary on GOV.UK. The summary will include a list of names or organisations that responded, but not people's personal names, addresses or other contact details.

Quality assurance

This consultation has been carried out in accordance with the government's consultation principles. If you have any complaints about the way this consultation has been conducted, please email: bru@energysecurity.gov.uk

Chapter 1: How to use this document

This chapter gives an overview of the publication package, including where readers can find different pieces of information.

1.1 What has been published?

This consultation document is part of a wider package of material published by the government relating to the Home Energy Model and the Future Homes Standard (FHS). Depending on your interests, you may be interested in all or part of this consultation document, as well as one or more of the other publications within this package. The full list of publications is as follows:

The Home Energy Model: FHS assessment consultation (this document)

What: This document seeks views on the parts of the new Home Energy Model methodology which are specific to demonstrating compliance with the Future Homes Standard. To aid understanding, this document is best read in conjunction with the main Home Energy Model consultation (see below).

Audience: This document will be of interest to those who want to understand the proposed standardised assumptions around occupancy, energy demand etc. to be used when assessing compliance with the FHS, as well as the methodology for the calculation of the proposed FHS compliance metrics.

Please note that this consultation does not include the proposed notional dwelling specifications. These are included in the FHS consultation.

The Home Energy Model consultation

What: The Home Energy Model consultation explains the overhaul to the SAP methodology and seeks views on the approach taken by the new Home Energy Model.

Audience: The Home Energy Model consultation will be of interest to those who want to understand the proposed changes to the SAP methodology and wider SAP landscape.

The Future Homes and Buildings Standards 2023 consultation

What: The Future Homes and Buildings Standards 2023 consultation (hereafter referred to as the "FHS consultation") seeks views on proposed changes to Part L of the Building Regulations and the accompanying statutory guidance for new dwellings and non-domestic buildings. These changes will be implemented in 2025.

Audience: The FHS consultation will be of interest to those who want to understand the proposed standards for the energy performance of new dwellings under the FHS.

Home Energy Model: FHS assessment consultation tool

What: Alongside the three consultations listed above, we have published a Home Energy Model: FHS assessment consultation tool, as a browser-based application. This consultation tool gives the opportunity to interact with the model by providing a demo user interface. See the user guide for more information.

Audience: The consultation tool will be of interest to those who want to test out the Home Energy Model: FHS assessment and understand whether different dwelling designs are likely to comply with the proposed Future Homes Standard.

Home Energy Model: FHS assessment technical documentation

What: This consultation is accompanied by several technical documents which go into further detail on the assumptions and validation exercises that have been carried out.

Audience: The technical documentation will be of interest to those who want to understand the justifications and evidence base behind the assumptions used in the model.

The Home Energy Model reference code

What: The full Python source code for the Home Energy Model and the Home Energy Model: FHS assessment has been published as a Git repository. This code is identical to that sitting behind the consultation tool. We are currently considering whether the open-source code could serve as the legal approved methodology for demonstrating whether new homes comply with energy performance standards in the Building Regulations.

Audience: The reference code will be of interest to those who want to understand how the model has been implemented in code, and those wishing to fully clarify their understanding of the new methodology. It will also be of interest to any potential contributors to the Home Energy Model.

1.2 Where can I find information on…?

Topic	Location
Overview of the Home Energy Model and how it differs from SAP.	Home Energy Model consultation
Overview of the Home Energy Model: FHS assessment and how it works with the Home Energy Model.	Chapter 2
Changes to the wider SAP landscape (e.g. how new technologies will be recognised, how software will be provided to energy assessors)	Home Energy Model consultation
Explanation of how a home's energy performance is modelled in the Home Energy Model.	Home Energy Model consultation and the accompanying technical documentation.
Information on how the Home Energy Model has been tested and validated	Home Energy Model consultation
Assumptions used when assessing compliance with the FHS (e.g. occupancy, energy demand, weather data).	Chapters 3, 4 & 5
Calculation methodology to determine FHS compliance	Chapter 5
The proposed FHS compliance metrics.	The FHS consultation
EPC reform, including EPC metrics and any model calculations or assumptions specific to EPCs.	*EPC reform is not covered in any of these publications. We are developing proposals to improve EPCs and intend to consult on these in the coming months.*

Chapter 2: The Future Homes Standard assessment: a wrapper for the Home Energy Model

The energy performance requirements for new homes are set through Part L of the Building Regulations. The Future Homes Standard (“FHS”) consultation seeks views on proposed changes to Part L, which will be implemented in 2025.

A dwelling’s compliance with these regulations will be determined using the government’s new Home Energy Model: FHS assessment, which will replace the current approved methodology, SAP 10.2. The Home Energy Model: FHS assessment will estimate the emissions and energy consumed by the dwelling under certain conditions and compare it to a benchmark notional dwelling (see Chapter 5).

One key aim of the Home Energy Model project has been to delineate between the different functions that were previously served by SAP. This has been addressed through the use of “wrappers”. This consultation covers the methodology for the first such wrapper to be developed: the FHS assessment wrapper.

$$\begin{aligned} &Home\ Energy\ Model\ core\ engine + FHS\ assessment\ wrapper \\ &= Home\ Energy\ Model{:}\ FHS\ assessment \end{aligned}$$

The Home Energy Model core engine and FHS assessment wrapper together make up the Home Energy Model: FHS assessment. We are consulting on the Home Energy Model: FHS assessment separately to the Home Energy Model core engine because this material is context specific and relies on a different evidence base to the core model.

For further information about the use of wrappers, please see section 3.5 in the Home Energy Model consultation.

2.1 What are the different parts of the Future Homes Standard assessment wrapper?

All new homes constructed in England must comply with Part L of the Building Regulations. An assessment of compliance is undertaken before a dwelling is occupied. This assessment is intended to articulate whether a given standard has been reached, which has been defined across a whole range of dwellings. Consequently, various parameters that the Home Energy Model core engine leaves open have been fixed within the FHS assessment wrapper and are not directly accessible to the user (represented by the “standardised inputs” in Figure 1). The wrapper also carries out the relevant notional dwelling comparison and produces the FHS compliance metrics (“wrapper outputs” in Figure 1), in addition to the core engine outputs (“additional outputs” in Figure 1).

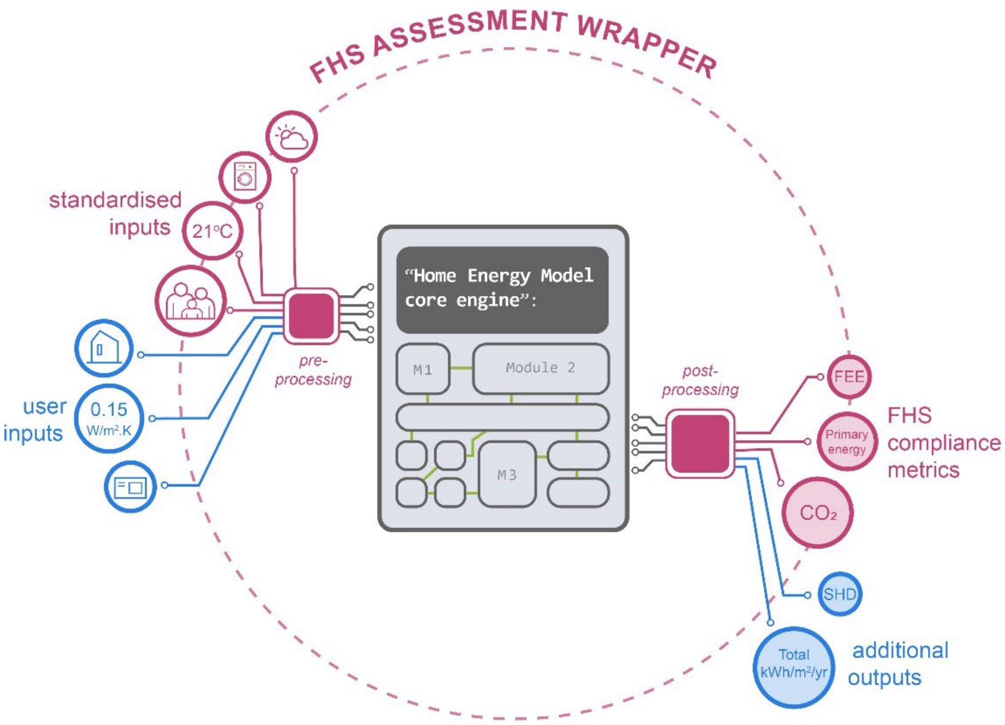

Figure 1 – Diagram of how the FHS assessment wrapper works with the Home Energy Model

The FHS assessment wrapper specifies the inputs and outputs of the Home Energy Model core engine (i.e. it wraps around the core engine).

At the pre-processing stage, the FHS assessment wrapper standardises inputs relating to:

- The calculation period and time resolution (The FHS assessment wrapper specifies that the dwelling is simulated for a period of 1 year, with a half-hourly time resolution)
- Occupancy and assumptions for energy demand, e.g. setpoint temperatures (Chapter 3)
- Weather data (Chapter 4).

At the post-processing stage, the FHS assessment wrapper applies a set of factors to the energy consumption results from the core engine in order to produce the FHS compliance metrics (Chapter 5).

1. **What are your views on the choice of inputs that have been standardised (i.e. the standardisations as set out in Chapters 3-5) vs left open as user inputs (i.e. as in the consultation tool)? Please explain your reasoning and provide any supporting evidence.**

2. **What are your views on the ease of populating or sourcing data for those user inputs? Please explain your reasoning and provide any supporting evidence.**

Chapter 3: Occupancy and energy demand

This chapter describes the standardisations and assumptions made in the FHS assessment wrapper relating to:

3.1 Occupancy

3.2 Space heating and cooling

3.3 Domestic hot water

3.4 Lighting, cooking, and appliances

For each topic, we provide:

A link to the relevant technical document, which provides further explanation and supporting evidence.

- The approach taken in SAP 10.2
- The approach taken in the FHS assessment wrapper

Key take-aways

3.1 Occupancy assumptions

Technical Paper: HEMFHS-TP-01 FHS occupancy assumptions

Occupancy is the number of people residing in a dwelling. In a real dwelling this will be an integer number of people, though they may not reside all year round and will typically be at home at different times. Occupants will also typically use energy differently from one another. Occupants will be of different ages, genders, sizes etc. which may have an affect on their direct energy use and the heat gains from the occupants themselves.

Data on occupancy collected by the English Housing Survey (EHS) shows large variations in real occupancy of similar dwellings, so there is significant uncertainty in predicting how many people will come to occupy a given new home when it is sold, or later in its life.

When real occupancy is not known (as in most Future Homes Standard assessments), an assumption is required in order to derive estimated energy demand. Increasing occupancy levels raises the modelled demand for hot water, cooking, lighting, and electrical appliance use, while it reduces the demand for space heating via the heat gains associated with these activities and also via metabolism (body heat).

The assumed occupancy must also be appropriate to the dwelling design and therefore should be derived from the known physical characteristics of the dwelling.

3.1.1 Standard occupancy

SAP has previously assumed a standard occupancy based on the total floor area. In the FHS assessment wrapper, we have added a dependency on the number of bedrooms as this reflects more realistically the way homes are occupied in England. This revised assumption is based on occupancy data from the EHS surveys 2017-2019.

The chart below, reproduced from the accompanying technical document, displays the SAP 10.2 assumed occupancy as a function of floor area, and the new set of assumed occupancy values. These are a function of floor area for 1-bedroom homes and constant values for homes with 2 or more bedrooms (see Table 1). For homes with five or more bedrooms, the assumed occupancy remains the same. Also displayed is a simplified representation of the EHS data used in the derivation of the new occupancy assumptions.

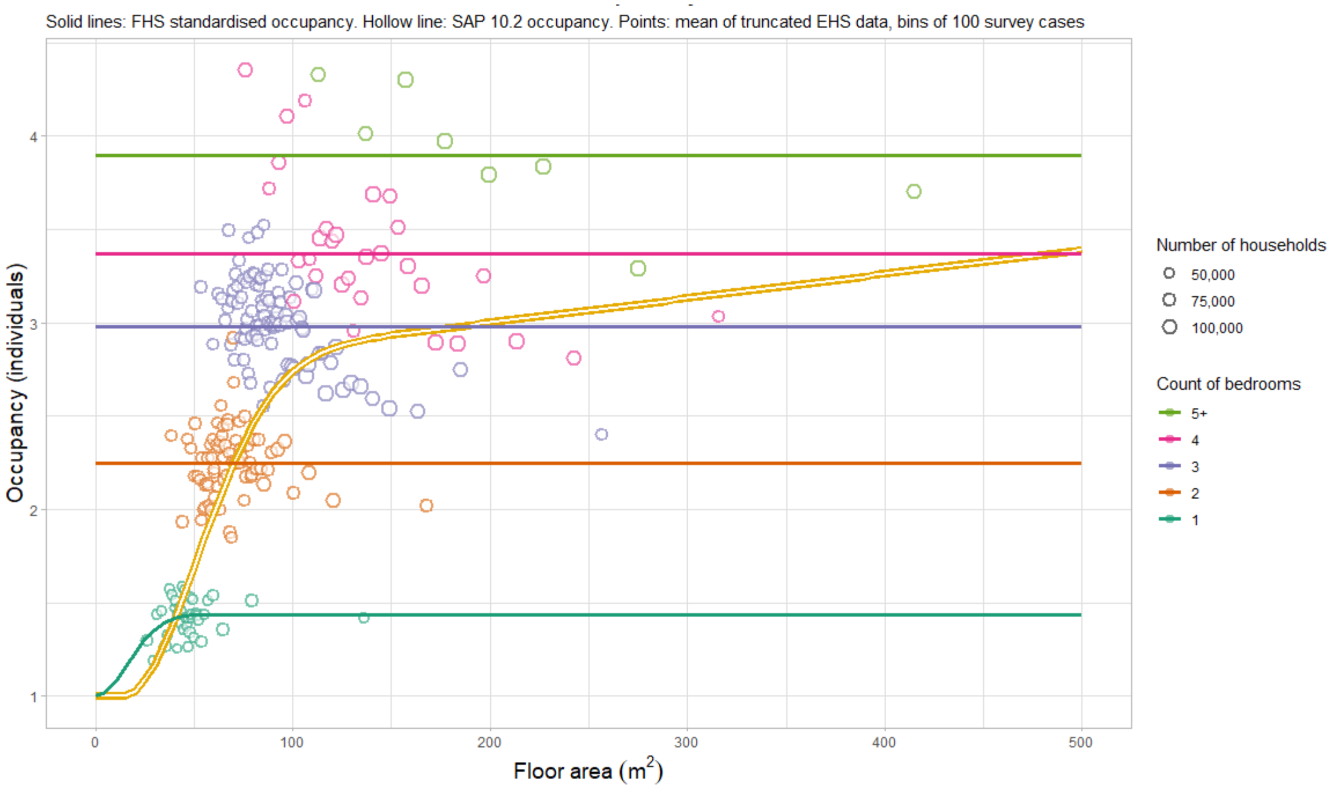

Figure 2 – FHS assessment wrapper and SAP 10.2 occupancy functions

It is clear from the EHS data that there is not a strong floor area dependence for occupancy unless the bedroom count is at least 3, and for these larger homes it is negative. That is, for a given number of bedrooms (3 or more), larger dwellings tend to have fewer occupants. Such a relationship was excluded from the assumed occupancy for the FHS assessment wrapper as it is a reflection of under-occupancy. Consequently, the curves best fitting the data are flat for all realistic floor area values, with the exception of one-bedroom properties.

To improve representation of design occupancy and further prevent under-occupancy influencing the results, the EHS data has been truncated to remove the least-occupied dwellings before fitting the occupancy curves.

No. of bedrooms	1	2	3	4	5 or more
Assumed occupancy	Function of floor area	2.25	2.98	3.37	3.90

Table 1 – Assumed occupancy for a given number of bedrooms.

Standard occupancy assumptions

- Based on analysis of recent English Housing Survey data, adjusted to avoid designing for under-occupation.
- Dependent on the number of bedrooms and total floor area.

3. What are your views on the proposed standard occupancy assumption? Please explain your reasoning and provide any supporting evidence.

3.1.2 Metabolic gains

Metabolic gains are transfers of heat energy from the occupants' bodies into the space. They occur when the occupants are at home, and the rate depends on what they are doing.

In SAP 10.2, each occupant is assumed to provide 60W on average, estimated from a standard output from an adult of 100W with a reduction for time away from home and for some occupants (e.g. children) emitting less heat.

The FHS assessment wrapper separates out the time-at-home occupancy factor and varying activity levels. Residents are assumed to provide 104W during the daytime and evening, and 74W overnight. These correspond to quiet activity and sleep respectively, for a typical adult, in BS EN ISO 7730:2005. The assumed activity levels have been lowered, as in SAP 10.2, to account for some residents being children but also to compensate for a proportion of metabolic activity being captured as evaporation (in the breath and in sweat) and not available as heat gains. The occupancy factors assumed are those used in the standard BS EN 16798-1:2019. Combining these gives the assumed rate of metabolic gains shown in Figure 3.

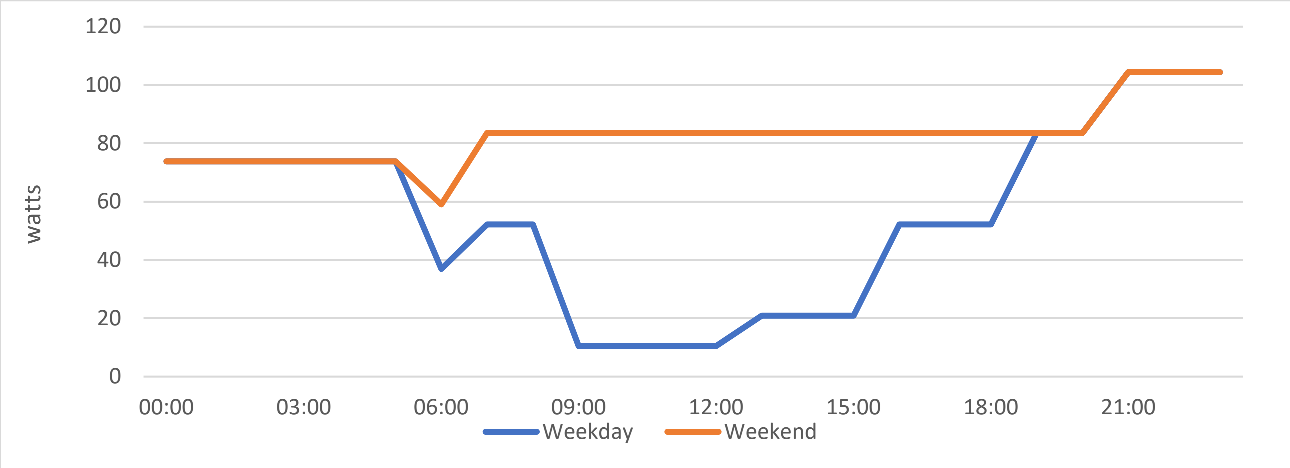

Figure 3 – Metabolic gains per occupant by time of day

We intend to further revise these assumptions with both updated evidence and an improved methodology. The ONS survey [Time Use in the UK 2023](#) provides contemporary (post-Covid) data both about time spent at home and of typical activity levels through the day. We also intend to apply the BS EN ISO 7730:2005 metabolic activity methodology to the English Housing Survey data on the composition of households by age. This will also take more accurate account of evaporation affecting metabolic gains.

Metabolic gains assumptions

- Metabolic gains into the space vary by day of the week and time of day.
- Based on BS EN ISO 7730:2005 and BS EN ISO 16798-1:2019.

4. What are your views on the assumptions for metabolic gains? Please explain your reasoning and provide any supporting evidence.

3.2 Space heating and cooling assumptions

Technical Paper: HEMFHS-TP-02 FHS space heating and cooling demand assumptions

The FHS assessment wrapper includes standardisations on:

3.2.1 Thermal zones and space heating setpoints

3.2.2 Space heating hours

3.2.3 Space cooling

3.2.1 Thermal zones and space heating setpoints

Thermal zones

The FHS assessment wrapper constrains the Home Energy Model to two thermal zones, one of which represents the primary living space and the other for the rest of the dwelling. This follows the approach used in SAP 10.2, where two zones are permitted with separate time and temperature heating controls. However, contrary to SAP 10.2, the two zones need to be inputted separately within the consultation tool. Also, unlike SAP 10.2, the Home Energy Model does not currently model thermal transfer between zones.

Space heating setpoints

In SAP 10.2, the primary living space (zone 1) and the rest of the dwelling (zone 2) have nominal temperature setpoints of 21°C and 18°C respectively. For zone 2 the model then derives a (higher) effective setpoint, to capture heat transfer between the zones and the effect of any thermostatic zone controls, or their absence.

For the FHS assessment wrapper, zone 1 has a setpoint temperature of 21°C and zone 2 has a setpoint of 20°C.

The zone 1 setpoint temperature assumption is derived from the 2017 Energy Follow Up Survey, where 21°C was the 75th percentile reported thermostat setting for the primary living space. The mean and median set-points were 20.4 and 20.0°C respectively, but some homes were underheated compared with their occupants' preferences. Selecting the higher percentile is intended to discount these from affecting the standardised assumption.

The zone 2 setpoint temperature assumption is taken from the design values within BS EN 16798-1:2019. In modern, well-insulated homes, it is unlikely that zone 2 will maintain an effective setpoint temperature much lower than the primary living space. In practice, in UK homes there is often not a specific setpoint temperature in non-living rooms with supply of heat to other rooms being determined by the living room thermostat.

Discussion

The zoning and setpoint assumptions used in the Home Energy Model can have a large effect on the calculated space heating demand for a home. Therefore, it is important that these assumptions are robust and based on the best-available evidence.

We are considering the following options:

- Moving to one zone with one setpoint temperature for some dwellings (those with smaller floor areas and/or a single heating control)
- Keeping two zones with no inter-zone heat transfer for all dwellings (as in the consultation version)
- Keeping two zones and adding inter-zone heat transfer (for all dwellings or some dwellings only, as above)

The advantages of moving to one zone include:

- **Increased usability:** reduced number of user inputs
- **Realistic:** consistent with how many new homes are designed and used in practice (with the exception of larger homes)

The advantages of keeping two zones include:

- **Increased flexibility:** ability to define different temperature control regimes for different parts of a home, including differing cooling regimes.
- **Better representation of larger homes:** more realistic representation of larger homes, which likely have more than one temperature control regime.

Adding inter-zone heat transfer has both advantages and disadvantages:

- **Better reflection of the building physics:** in reality, there is an element of heat transfer between zones.
- **Increased complexity:** adding inter-zone heat transfer is likely to increase the runtime of the simulation.
- **Limited returns:** adding inter-zone heat transfer may offer minimal benefits over merging the two zones into one (particularly if the inter-zone heat transfer is large).

For all these options, we will determine the appropriate setpoint temperature assumptions based on a review of recent guidance and data on temperature controls in new-build homes.

Thermal zones and space heating setpoint assumptions

- Two separate heating zones (primary living space and elsewhere).
- Setpoint temperature of 21°C for the primary living space, derived from EFUS data.
- Setpoint temperature of 20°C elsewhere.

5. Do you think the FHS assessment wrapper should keep using two thermal zones for all dwellings? Y/N. Please provide your reasoning and any supporting evidence.

6. If the FHS assessment wrapper keeps two thermal zones, do you think we should introduce inter-zone heat transfer? Y/N. Please provide your reasoning and any supporting evidence.

7. What are your views on heating setpoints for (a) one zone; (b) two zones without inter-zone heat transfer (i.e. the current assumptions given above); and (c) two zones with inter-zone heat transfer? Please provide reasoning and supporting evidence.

3.2.2 Space heating hours

In SAP 10.2, the primary living space is assumed to be heated in the morning and evening, between 07:00–09:00 and 16:00–23:00. If a dwelling has separate controls for the rest of the dwelling (i.e. zone 2) then this turns on later in the afternoon, 07:00–09:00 and 18:00–23:00.

For the Home Energy Model: FHS assessment, the dwelling is assumed to follow the most usual heating pattern found in the Energy Follow Up Survey (EFUS) 2017. This is a bimodal morning and evening pattern on weekdays, and all-day heating at weekends, which is typical of central heating with a gas boiler and radiators. In table form, the heating hours are:

	Weekday (living area / single control)	Weekday (non-living area, separate time and temperature control)	Weekend
On1	07:00	07:00	08:30
Off1	09:30	09:30	22:30
On2	16:30	18:30	-
Off2	22:00	22:00	-

Table 2 – Assumed heating hours in the FHS assessment wrapper.

To give a fair comparison between different heating systems, the FHS assessment wrapper specifies the same heating demand periods regardless of the characteristics of the system.

Many homes built to the FHS will be heated using heat pumps, and therefore may be more suited to a continuous rather than intermittent heating schedule. We have made allowances to ensure these heating systems can benefit from a continuous heating regime by enabling greater user choice when defining space heating. For example, the FHS assessment wrapper allows users to specify a setback temperature and/or “advanced start period”, to allow the system to run outside the specified demand periods. Fully continuous heating is therefore permitted in FHS assessment models at the user’s discretion (see HEMFHS-TP-02).

Heating season

SAP 10.2 assumes that the heating season covers the months of October to May (that is, the heating is assumed to be off in June-September regardless of the temperature inside the dwelling). Currently the FHS assessment wrapper does not specify a heating season. Whether the heating is on or off depends only on the control settings and the dwelling’s space heating demand (see section 5.1.1 in the Home Energy Model consultation).

Heating season behaviour (e.g. toleration of low temperatures over short periods during months that are generally warm) is known to occur and may influence energy demand during the spring and autumn particularly. We will undertake further analysis to determine the most appropriate assumptions to use in the context of a high time-resolution model. Little to no space heating is expected in the months of June-September within an FHS assessment model, even without adopting the SAP 10.2 assumption.

Space heating hours assumptions

- Standard heating hours based on EFUS 2017 data.
- Ability to specify warm-start and setback temperatures to ensure all system types can work efficiently, while serving the same core heating hours.
- Currently no defined heating season.

8. What are your views on the assumptions for space heating hours? Please provide your reasoning and any supporting evidence.

9. What are your views on the ability to specify a control scheme (e.g. setback temperatures and "advanced start" periods) that works for the system being installed? Please provide your reasoning and any supporting evidence.

10. What are your views on the treatment of the heating season vs non-heating season (months where the heating is assumed to be off regardless of the temperature)? Please provide your reasoning and any supporting evidence.

3.2.3 Space cooling

In SAP 10.2, when a cooling system is present, it is assumed to operate for 6 hours a day during June, July, and August only, with a set-point temperature of 24°C for the whole conditioned area.

In the Home Energy Model: FHS assessment, the demand for cooling is modelled dynamically, governed by additional assumptions (see section 5.1.1 in the Home Energy Model consultation). An unchanged active cooling setpoint of 24°C is assumed (taken as the central figure from CIBSE Guide A: Environmental Design). As with space heating, the FHS assessment wrapper does not specify a cooling season (i.e. specific months of the year where the cooling system is used).

In the zone containing the primary living area, the hours of active cooling are assumed to be the same as the heating hours. In zone 2, hours of active cooling are taken to run overnight from 22:00 – 07:00. This is the assumption used in the CIBSE TM59 methodology for assessing overheating risk in homes.

	Zone 1 (weekday)	Zone 1 (weekend)	Zone 2
On1	07:00	08:30	22:00
Off1	09:30	22:30	07:00
On2	16:30	-	-
Off2	22:00	-	-

Table 3 – Assumed active cooling hours in the FHS assessment wrapper.

It is assumed that occupants will open their windows once the temperature rises above 22°C, (figure taken from Approved Document O, 2021 edition). Opening the windows will cool the modelled dwelling and may remove the need for active cooling[1]. If the temperature still rises above 24°C with the windows open, and a (fixed, non-portable) cooling system is present, it is assumed that occupants will close the windows and start using their cooling system.

The window opening schedule (outside of which the windows will not open regardless of the temperature) has been taken from Approved Document O (see Table 4). This schedule has been set to ensure there is not a reliance on window opening to provide cooling at night, where there is a greater chance of a noise or security issue.

	Zone 1 (weekday)	Zone 1 (weekend)	Zone 2
On	09:00	09:00	08:00
Off	22:00	22:00	23:00

Table 4 – Assumed window ventilation hours in the FHS assessment wrapper.

Cooling systems are still rare in homes in the UK, and we are likely to explore this area further when new evidence of how they are used in this country becomes available.

Please note that a separate Part O (overheating) assessment should be undertaken before running the Home Energy Model: FHS assessment. This is because the cooling requirement determined through Part O informs the user input to the model, which helps to define the notional building.

Space cooling assumptions

- Active cooling systems (if present) have a setpoint of 24°C and are used in living rooms during the day and in bedrooms overnight.
- Currently no defined cooling season.
- Windows open once temperature rises above 22°C and are only openable during the day.

11. What are your views on the proposed assumptions for the use of space cooling systems? Please provide your reasoning and any supporting evidence.

[1] Currently windows are assumed to be openable; however, there may be cases where this is not true. We will consider giving the user the option to specify whether this is the case.

3.3 Domestic hot water assumptions

Technical Paper: HEMFHS-TP-03 FHS domestic hot water assumptions

Domestic hot water ("DHW") includes the hot water drawn for baths and showers or run at the taps. The FHS assessment wrapper includes standardised assumptions for:

3.3.1 Volume of hot water demand

3.3.2 Times of hot water use

3.3.3 Hot water / mixed water temperatures

3.3.4 Water heating hours

3.3.5 Cold water feed temperatures

The assumptions used in SAP 10.2 derive from a study by the Energy Saving Trust published in 2008. For the Home Energy Model: FHS assessment this analysis has been updated with usage data from a sample of 45,000 combi boilers in UK homes, taken in 2021-22 (the "Connected Devices" study)[2]. In this study, the boilers supplied hot water directly, so this usage data is a proxy for underlying household demand.

3.3.1 Volume of hot water demand

In SAP 10.2 each occupant is assumed to take a certain number of baths and showers a month. These consume an amount of hot water dependent on the flow rate of any showers and the volume of any baths. There is also a demand per person for other uses of DHW and a fixed baseline demand. A monthly adjustment accounts for people using more hot water in winter and less in summer. Typical consumption in SAP 10.2, in a home with a combi boiler, might be 120 litres a day of unmixed hot water for a two-person household or 160 litres a day for three people.

In the Home Energy Model: FHS assessment, the typical hot water demand depends on occupancy, with additional occupants requiring a diminishing amount of additional water, giving the totals shown in Table 5 below. The change from the SAP 10.2 assumption reflects how households' typical water use has changed over the last decade, with an increase in low-flow appliances and a gradual shift from baths to showers. The new relationship is estimated by rescaling the Energy Saving Trust data to match the distribution of hot water use found in the contemporary Connected Devices data, as described in the technical paper.

[2] As detailed in DESNZ Research Paper: *Domestic Hot Water Use: Observations on hot water use from connected devices*. This dataset, although large, may not be fully representative of the UK as a whole.

Household size	1	2	3	4	5	6
Total consumption, litres/day	60.3	99.3	133.0	163.6	192.1	219.1

Table 5 – Daily consumption of unmixed hot water

The consumption data used to set these standard values was measured at the boiler outlet. Of this, 15% of the consumption was assumed to be hot water left in the pipework and not reaching the tap while the remaining 85% met occupants' demands. This typical demand is further adjusted for bath sizes and shower flow rates when building the schedule of hot water events for the dwelling, as described below in section 3.3.2. The Home Energy Model then takes the dwelling's actual pipework lengths and losses into account to calculate the water needed to supply these events.

Volume of hot water demand assumptions

- Revised assumptions based on field data from 45,000 combi-boilers.
- Lower hot water consumption per occupant than assumed in SAP 10.2.

12. What are your views on the assumptions for the volume of hot water demand? Please provide your reasoning and any supporting evidence.

3.3.2 Times of hot water use

The Home Energy Model allows for a detailed schedule of hot water "tapping events" to be specified at each half-hourly timestep. The Home Energy Model: FHS assessment generates a realistic pattern of events across an entire simulated year, to test not only how the home's hot water system meets the average demand, but also whether it can cope with peaks in use. It also improves the realism of incidental heat gains from hot water use.

This component of the model has no analogue in the SAP monthly methodology. A detailed algorithm is specified in the accompanying technical document (see HEMFHS-TP-03)

The schedule of tapping events is generated from a frequency table based on usage data from the Connected Devices study. This frequency table shows how many showers, baths and other water events are drawn, on average, on each day of the week and each hour of the day, based on data from real homes. It also shows for how long the taps are running.

With the volume of hot water demand calculated from the number of occupants (see section 3.3.1), a standardised schedule for the dwelling is pseudo-randomly generated from these frequencies (see Figure 4 for an example schedule). Bath and shower events are allocated between the baths and showers present in the home. As in the SAP 10.2 methodology, monthly factors adjust the calculated demand to account for seasonal differences in hot water use.

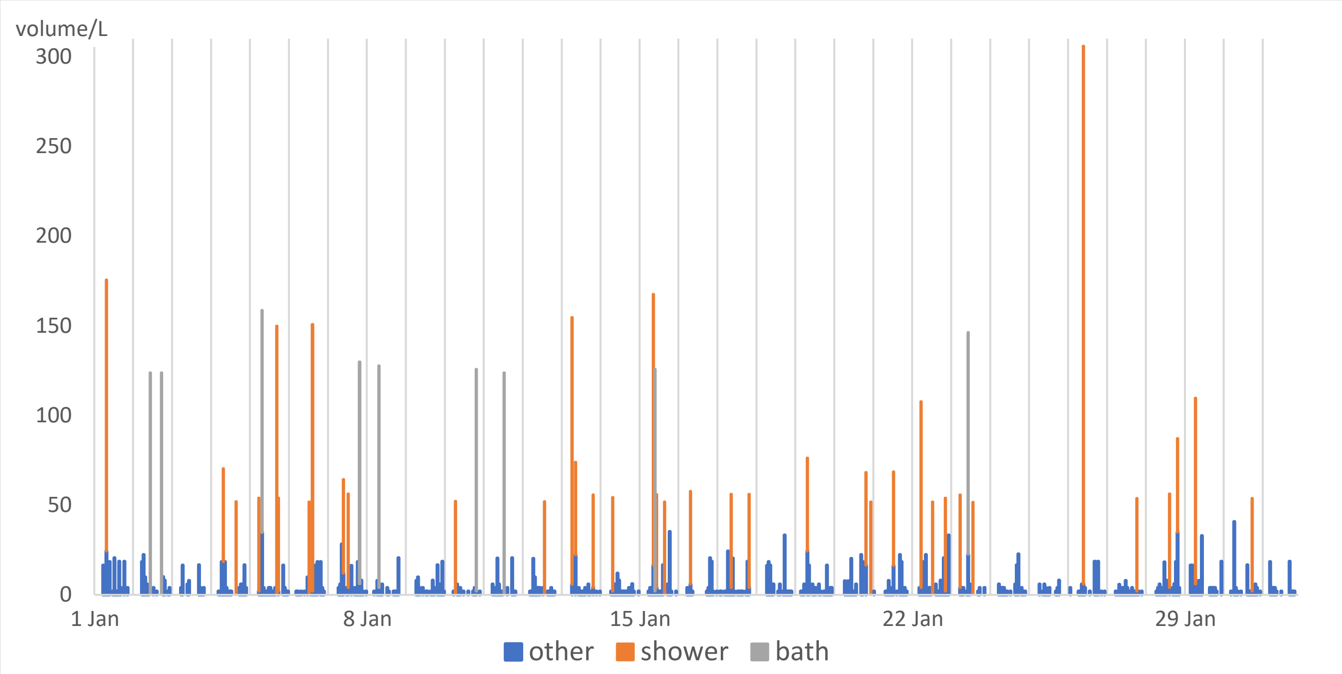

Figure 4 - Example generated profile for a 5-bedroom house, showing total volume of hot water tapping events per hour for each event type.

Times of hot water use assumptions

- Pseudo-randomly generated schedule of hot water use, based on number of occupants and the number of baths and showers present.
- Assumptions based on field data from 45,000 UK combi-boilers.

13. What are your views on the pseudo-randomly generated hot water use schedule, including the algorithm generating it? Please provide your reasoning and any supporting evidence.

3.3.3 Hot water / mixed water temperatures

In the FHS assessment wrapper the temperature of hot water delivered to the tap is standardised at 52.0°C. The temperature of mixed water then used in showers is 41.0°C and baths are run at 42.0°C. These assumptions are unchanged from SAP 10.2.

The SAP assumption for hot water delivery temperature was evidenced by the Energy Saving Trust study, which found that average delivery temperatures were consistent across the year, although they were lower for combi boilers (50.0°C) than regular boilers with a hot water cylinder (52.9°C). In the Connected Devices combi boiler sample, the mean delivery temperature by event was lower again, at 48.7°C. The median setpoint for combi boilers in the

Connected Devices sample was 55°C. Without definitive new evidence here the SAP 10.2 figure of 52.0°C remains a plausible standard delivery temperature across technologies.

The hot water cylinder setpoint is the target temperature to which the heating system raises the hot water cylinder (if present) when it is active. In the FHS assessment wrapper the hot water cylinder setpoint is 60.0°C. This is the required temperature for legionella control, as supplied by the Health and Safety Executive.

After reaching this temperature the system permits the cylinder to cool to the hot water supply temperature before water heating restarts. During water heating hours (see section 3.3.4) the contents of the cylinder will be heated back to the setpoint temperature if the water falls below the delivery temperature (i.e. below 52.0°C). This behaviour has no direct analogue in SAP 10.2, where the energy content of hot water is calculated for a supply at a constant 52.0°C.

Hot water / mixed water temperature assumptions

- Hot water is delivered to the tap at 52.0°C.
- Shower temperature of 41.0°C and baths run at 42.0°C.
- Hot water cylinder has a setpoint temperature of 60.0°C and a minimum temperature during water heating hours of 52.0°C (i.e. the delivery temperature).

14. What are your views on the proposed hot water / mixed water temperature assumptions? Please provide your reasoning and any supporting evidence.

3.3.4 Water heating hours

In the FHS assessment wrapper, the water heating hours (during which the heating system provides heat to the hot water cylinder if it cools below 52°C) are set by default to last throughout the day. This means that the cylinder temperature will cycle between the setpoint (60°C) and delivery temperatures (52°C) continuously, ensuring that hot water is available at the requisite temperature. This reduces the likelihood of a heating system failing to reach setpoints due to it having to warm both the cylinder and the space at the same time.

Instantaneous systems (including combi boilers) are also required to be always available for water heating. There is not currently the facility to set an alternative water heating schedule, and the schedule is the same irrespective of the choice of fuel tariff.

Hot water cylinders must also hold the water at the setpoint temperature for a period overnight (midnight to 7am), for legionella control. This is based on guidance from the Health and Safety Executive.

Water heating hours assumptions

- Cylinder heating and instantaneous water heating is available throughout the day.
- Hot water cylinders run an overnight legionella cycle where the 60°C setpoint is maintained from midnight to 7am.

15. What are your views on the assumptions for water heating hours? Please provide your reasoning and any supporting evidence.

3.3.5 Cold water feed temperatures

The temperature of the cold-water feed to the DHW system depends on the time of year, and on whether water is drawn directly from the mains or from a header tank. The average monthly temperatures are derived from the Energy Saving Trust 2008 study and have not changed from those in SAP 10.2. We will consider developing these assumptions in future to integrate regional weather data (see Chapter 4).

Cold water temp. /°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
From header tank	11.1	11.3	12.3	14.5	16.2	18.8	21.3	19.3	18.7	16.2	13.2	11.2
From mains	8.0	8.2	9.3	12.7	14.6	16.7	18.4	17.6	16.6	14.3	11.1	8.5

Table 6 – Monthly cold water feed temperatures

Additionally in the Home Energy Model, a time-of-day factor is introduced, as the cold feed is expected to drop in temperature by 1.5°C between midnight and 6am before recovering during the first part of the day.

Cold water feed temperature assumptions

- Depends on time of year, and whether water is drawn from the mains or a header tank.
- Temperature drops overnight and recovers in first part of the day.

16. What are your views on the cold water feed temperature assumptions? Please provide your reasoning and any supporting evidence.

3.4 Lighting, cooking, and appliances assumptions

Technical Paper: HEMFHS-TP-04 FHS appliances assumptions

Lighting, cooking and the use of other electrical appliances all consume energy and thereby release heat into the home. In the Home Energy Model these are modelled with a schedule of electricity consumption for each half-hour timestep, and a fraction (the “availability factor”) for the proportion of that electrical energy that is absorbed into the living space as heat.

The FHS assessment wrapper includes standardised assumptions for the **total demand**, **time-of-use**, and **availability factors** for:

3.4.1 Lighting

3.4.2 Cooking

3.4.3 Appliances

It also includes assumptions on:

3.4.4 Cold water and evaporative losses

3.4.1 Lighting

In SAP 10.2, total **lighting demand** (in lumens) depends on both floor area and occupancy: a 1% increase in either floor area or occupancy gives a 0.47% increase in lighting demand. The energy needed to meet this demand is then calculated from an average of the efficacies (in lumens per watt) of the lights in the dwelling as specified by the user.

The FHS assessment wrapper follows this same methodology, but the assumptions have been updated. In a small home the total lighting demand is 60% higher than that assumed in SAP 10.2, and for a large home it is 40% more.

This revised assumption takes into account electricity consumption in the Energy Follow Up Survey (EFUS) 2017 as well as appliance use data from the Household Electricity Survey 2012. These surveys show that although lighting has become more efficient in the last decade, households are also using more light.

The FHS assessment wrapper is able to simulate homes at a 30-minute time resolution, and therefore we have introduced assumptions around the lighting’s **time of use**, which were not present in SAP 10.2. The time of use profile shows that lights are typically used more in the morning and in the evening. The profile varies by month, where in the winter, lights are used more during the daytime and come on earlier in the evening (see Figure 5). The same profile is used for weekdays and weekends. These profiles derive from survey data gathered in the 1990s.

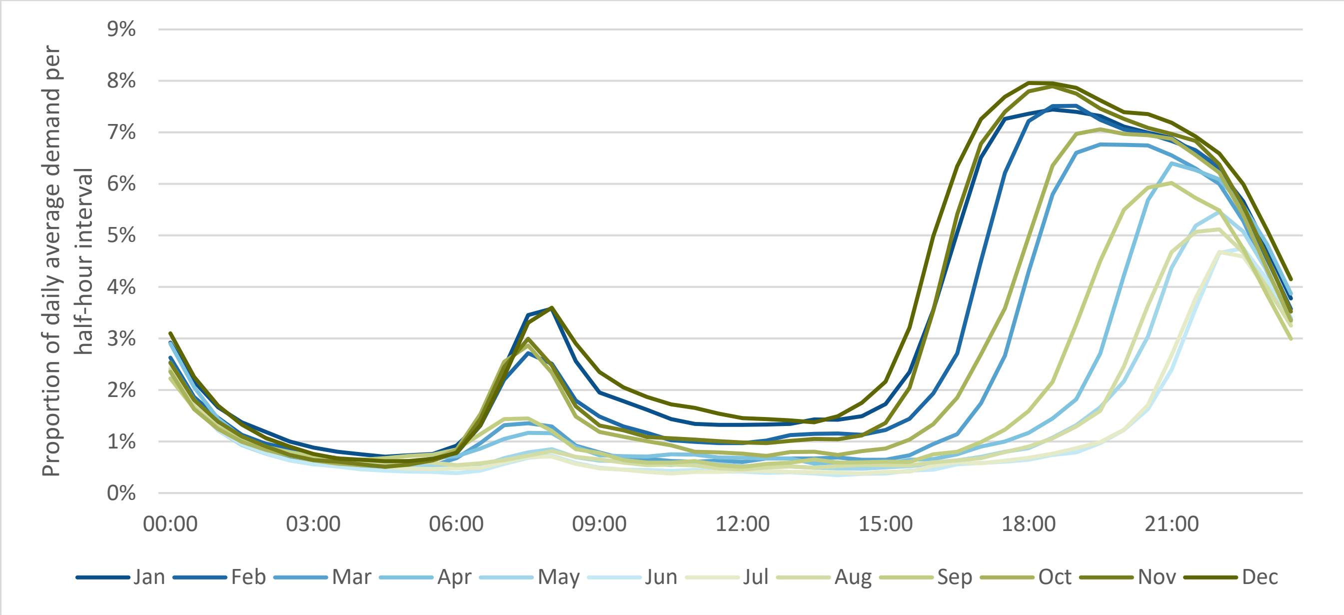

Figure 5: Relative proportion of lighting demand by time of day and month.

The **availability factor** for thermal gains from lighting is 85%, as 15% of lighting use is assumed to be external to the building. This is unchanged from the SAP 10.2 assumption.

Note that the consultation tool currently only collects data on the lighting efficacy in each zone, with the overall lighting demand being set as above. We will consider additionally collecting information on the number of fixed light fittings in each zone, to better estimate the total maximum lumens output for the specific dwelling. This maximum could then be scaled according to the time of use profile.

Lighting assumptions

- Standard demand is estimated from 2017 EFUS data and has increased compared to SAP 10.2 assumptions.
- Time of use profile estimated from 1990s survey data.
- Availability factor for thermal gains is unchanged from the SAP 10.2 value of 85%.
- User enters an overall lumens per Watt efficacy value for lighting in each zone.

17. What are your views on the proposed assumptions for lighting demand, time of use and thermal gains availability? Please provide your reasoning and any supporting evidence.

3.4.2 Cooking

The SAP 10.2 model does not make a full calculation of **cooking energy demand**. Implicitly, the thermal gains calculation assumes half of cooking demand is provided by electricity, and half by gas.

In comparison, the FHS assessment wrapper takes account of the fuel type of the cooking appliances installed in the dwelling (i.e. whether the main hob and oven are electric, mains gas, or split between these). Cooking energy demand is assumed to depend on the number of occupants, and has been estimated from Energy Follow Up Survey (EFUS) 2017 data.

The **time-of-day profile** for when cooking is done is based on survey data from 1999[3], showing peaks at lunchtime and in the early evening. The same profile is used for weekdays and weekends.

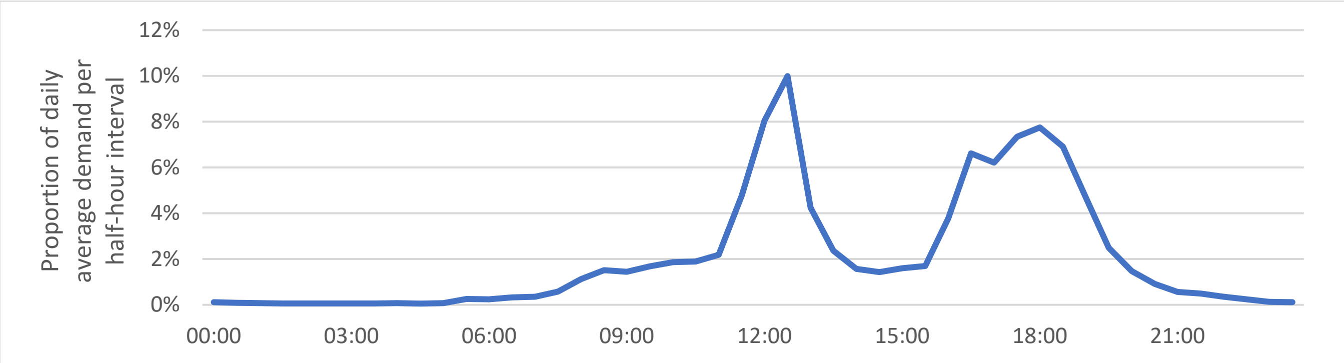

Figure 6: Relative proportion of cooking demand by time of day.

The SAP 10.2 thermal gains calculation assumes an **availability factor** of 75% for gas and 90% for electric cooking. In the FHS assessment wrapper this is revised downwards to 50% for all fuel types. This value is taken from the Passivhaus Planning Package model and reflects an assumption about the amount of heat lost to ventilation (e.g. cooker hoods) or poured away (e.g. from pouring away boiling water).

We will look to develop these assumptions further, to reflect the changing cooking technologies used in UK households and changes in occupancy patterns. We will also consider developing an “events schedule” for cooking, similar to that used for hot water (see section 3.3.2). We particularly welcome additional evidence here.

Cooking assumptions

- Cooking energy demand depends on number of occupants and is estimated from 2017 EFUS data.
- Unlike in SAP 10.2, cooking energy consumption is based on the fuels used by the installed cooking appliances.

[3] Unpublished research by the Electricity Association in 1999-2000.

- Time of use estimated from 1999 survey data.
- Availability factor of 50% for thermal gains.

18. What are your views on the proposed assumptions for cooking energy demand, time of use, and thermal gains availability? Please provide your reasoning and any supporting evidence.

3.4.3 Appliances

Appliances in the Home Energy Model include all the remaining uses of electricity in the home, after the building services systems, lighting and cooking have been accounted for.

In SAP 10.2, total **appliance demand** is estimated on an aggregated basis, as a function of both floor area and occupancy. The same methodology has been used for the FHS assessment wrapper, but the relationship has been re-derived.

For all homes the FHS assessment wrapper appliance demand is about three-quarters of the demand for the same home under the SAP 10.2 assumptions. The new relationship has been estimated from data gathered in the Energy Follow Up Survey (EFUS) 2017, a significant update on the previous data gathered in 1997. This reflects the fact that many household appliances, especially white goods and televisions, have become more efficient in recent years.

The FHS assessment wrapper is able to simulate homes at a 30-minute time resolution, and therefore we have introduced assumptions around appliances' **time of use**, which were not present in SAP 10.2. The **time-of-day profile** shows that appliance use peaks in the late afternoon. The profile varies by month, with greater appliance use during the winter (see Figure 7). The same profile is used for weekdays and weekends.

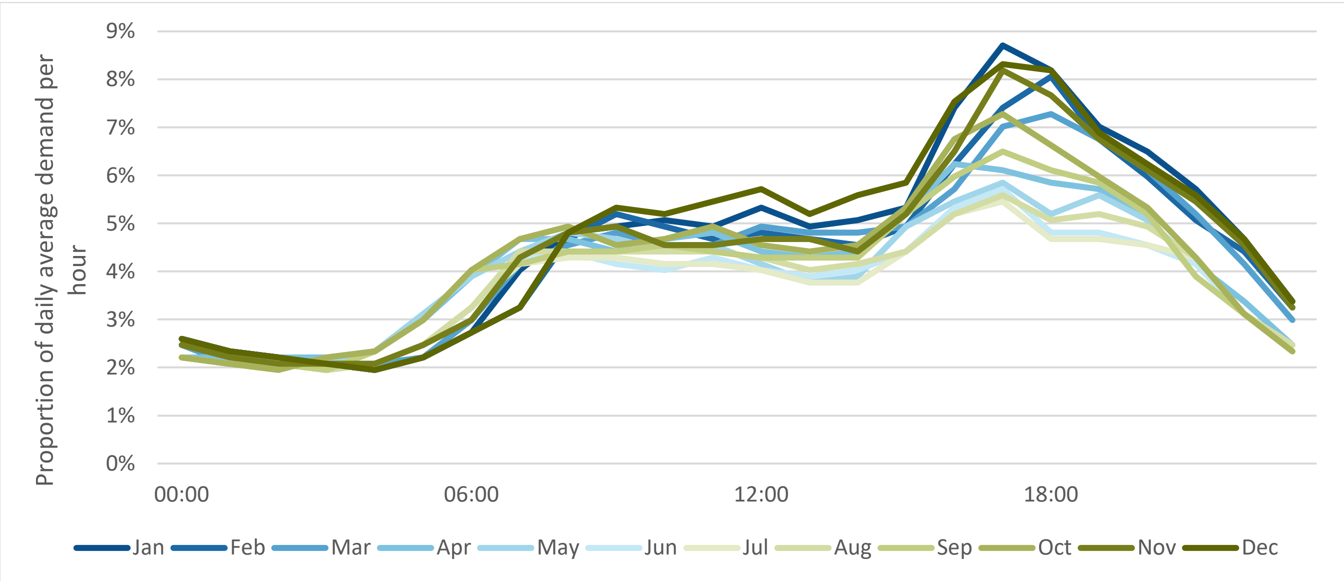

Figure 7: Relative proportion of appliance energy demand by time of day and month.

These profiles are derived from EFUS 2017 monitoring data[4]. They represent an average over many dwellings, and in a single dwelling the electricity use profile will be significantly more variable than Figure 7 suggests. Tumble dryers, kettles, and other intense electricity draws have a strong influence on overall peak electricity demand and the utilisation of solar PV and other microgeneration.

The SAP 10.2 model assumes all energy consumed by appliances contributes to thermal gains, an **availability factor** of 100%. In the FHS assessment wrapper this is reduced to 70%. The revised factor makes an allowance for hot water drained and hot air vented by washing and drying appliances, and for exterior devices. In combination with the reduced overall consumption, typical heat gains from appliance use in the FHS assessment wrapper will almost halve compared to SAP10.2.

In future, we will consider replacing the ‘top down’ aggregated estimate of appliance demand with a realistic ‘bottom up’ calculation of the energy demand of individual appliance types. We hope this may increase the accuracy of the calculation and better reflect the actual products being used. Note that the consultation tool contains some user input fields relating to appliances that would be used to facilitate this bottom-up approach.

We also intend to look into generating a “noisy” event profile, similar to that used for hot water tapping (see section 3.3.2). We hope this would provide a more realistic profile of appliance use, which will be important for improving the calculation of electricity self-consumption and storage (e.g. self-consumption of solar PV generation, battery charge/discharge).

Appliances assumptions

- Appliance demand is dependent on floor area and occupancy.
- Time of use estimated from EFUS 2017 monitoring data (currently an averaged profile not reflective of real variability in electricity draws).
- Availability factor of 70% for thermal gains.

19. What are your views on the assumptions for appliance energy demand, time of use, and thermal gains availability? Please provide your reasoning and any supporting evidence.

3.4.4 Cold water and evaporative losses

Heat energy is lost from the space in the dwelling to evaporation and to incoming cold water as it warms to room temperature. Sources of evaporation in the home typically include damp

[4] EFUS time of use data does not offer a breakdown by end-use between appliances, lighting, and cooking. Since appliances are assumed to make up the majority of electricity demand in non-electrically heated households, this profile has been adopted without modification for appliance demand. Lighting and cooking make use of other data sources as noted in sections 3.4.1 and 3.4.2.

towels after bathing, laundry dried indoors, washing-up, hair-drying and respiration by house plants.

The FHS assessment wrapper assumes a constant rate of cold water and evaporative losses of 40W per occupant. This is unchanged from the SAP 10.2 assumptions and is equivalent to evaporating 1.4 litres of water per day per person.

20. **What are your views on the assumptions for cold water and evaporative losses? Please provide your reasoning and any supporting evidence.**

Chapter 4: Weather assumptions

Technical Paper: HEM-TP-03 External conditions

The Home Energy Model uses hourly weather data to simulate the energy performance of a home. Some examples include using:

- External temperature to calculate the fabric heat loss and source temperature for air source heat pumps.
- Solar radiation to calculate solar gains and energy produced by solar PV.
- Wind speed to calculate the infiltration rate.

This weather data will be standardised in the FHS assessment wrapper. The detail of how standardised weather data will be integrated into the Home Energy Model: FHS assessment will be explored as part of changes to the delivery model and provision of software (see section 3.2 in the Home Energy Model consultation).

The consultation tool uses weather data from CIBSE's Test Reference Year (TRY). The TRY is composed of 12 separate months of data, each representing an average 'month' compiled from many years of Met Office observations.

Unlike in SAP 10.2, the weather data used in the consultation tool is the "future" TRY[5], and is based on UK climate projection scenarios from the Met Office (UKCP09). Given that UK climate data displays clear trends, moving to forward-looking scenarios in new-build Part L assessments will help to ensure that new homes are assessed against the more relevant circumstances for their operational lifetime.

In SAP 10.2, metrics relating to Part L compliance are calculated using weather data from the East Pennines (see Figure 8(a)), which is intended to represent average UK weather.

The government is consulting on using regional weather data for FHS assessments as part of the FHS consultation.

While we await the outcome of the FHS consultation on the use of regional weather data, the full set of CIBSE future TRYs for England, covering ten locations, has been made available in the consultation tool (see Figure 8(b)).

[5] The specific scenario being used is the High (50th percentile) 2020s TRY (10 locations across England).

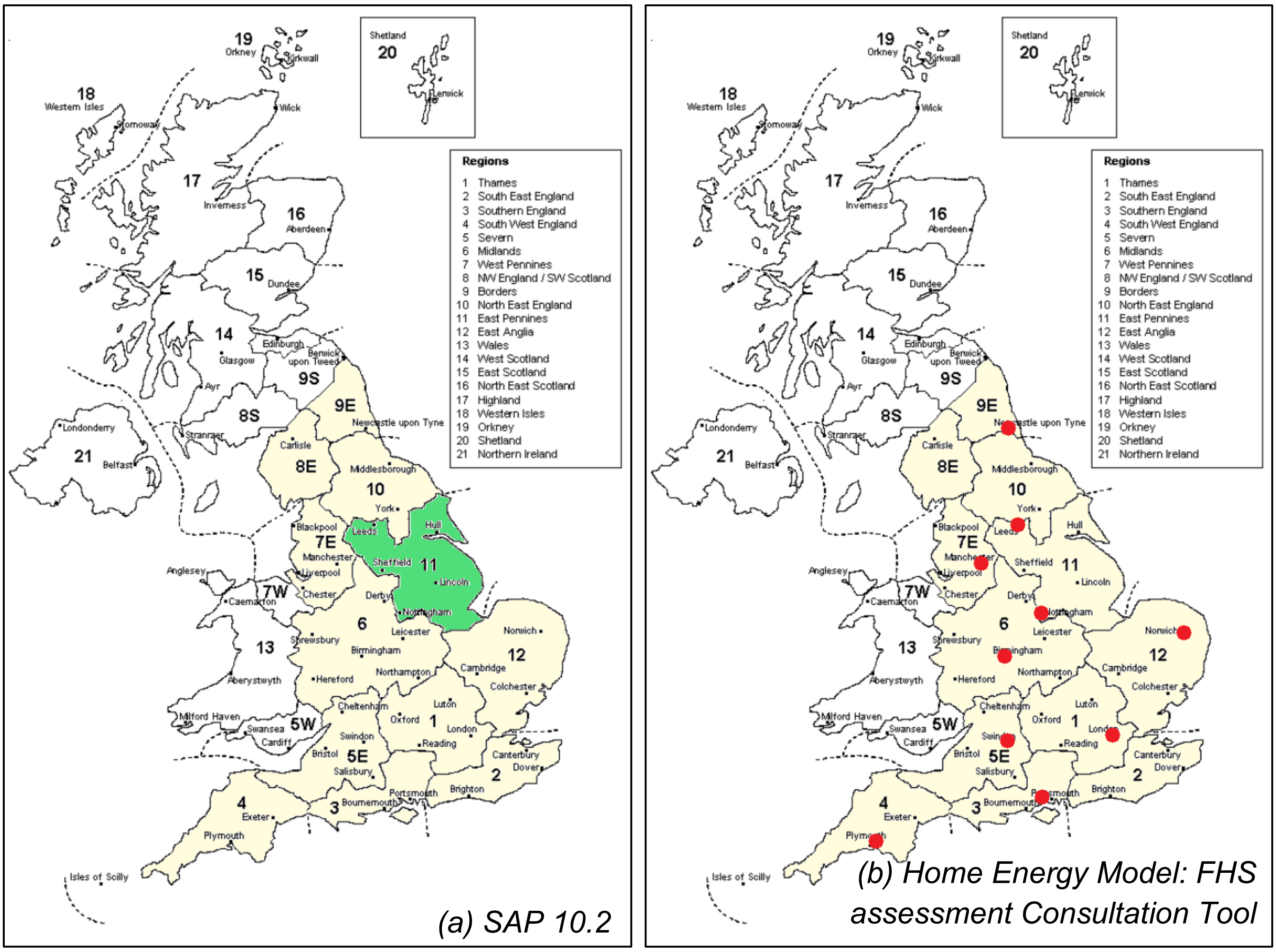

Figure 8(a) – Map showing the location of the East Pennines weather region (number 11) used for SAP 10.2 Part L assessments (see Appendix U in the SAP 10.2 specification).

Figure 8(b) – Map showing the ten English weather locations available in the consultation tool (represented by the red dots).

In both maps, England is highlighted in light yellow.

Weather assumptions

- Time resolution of weather data increased from monthly to hourly.
- Uses a forward-looking weather profile.
- 10 weather locations have been provided for the consultation tool.

21. What are your views on the use of climate projections rather than historical averages for the weather assumptions within the model? Please provide your reasoning and any supporting evidence.

Chapter 5: FHS compliance metrics

This chapter describes the compliance metrics produced by the FHS assessment wrapper, and the fuel assumptions used to calculate them.

5.1 Metrics

The following performance targets are proposed for new homes under the FHS:

- Target emission rate (TER)
- Target primary energy rate (TPER)
- Target fabric energy efficiency (TFEE)

The FHS consultation proposes that compliance with these targets will be determined by comparing a dwelling's energy performance against a theoretical dwelling of the same size, shape, orientation etc. (the "notional dwelling"). Using a notional dwelling approach means that the exact values of the performance targets listed above will be unique to each dwelling (e.g. a flat will have different targets to a detached home).

Please see the FHS consultation for the rationale and proposed options relating to the FHS performance targets and notional dwelling approach.

5.1.1 Simulations used to produce compliance metrics

In order to determine whether a dwelling complies with the FHS performance targets, the Home Energy Model: FHS assessment runs four simulations:

Table 7 – The FHS assessment wrapper simulations used to determine FHS compliance.

	Name	Simulation	Outputs
1	"Actual dwelling"	Actual dwelling with: • FHS assessment assumptions (see Chapters 3 and 4)	• Dwelling emission rate (DER) • Dwelling primary energy rate (DPER)
2	"Notional dwelling"	Notional dwelling for simulation 1	• Target emission rate (TER) • Target primary energy rate (TPER)
3	"FEE dwelling"	Actual dwelling with: • FHS assessment assumptions	• Dwelling fabric energy efficiency (DFEE)

		• Fabric energy efficiency (FEE) calculation assumptions	
4	"Notional FEE dwelling"	Notional dwelling for simulation 3	• Target fabric energy efficiency (TFEE)

In each case, the notional dwelling is produced by overwriting various user input parameters with standard values. The FEE dwelling (simulation 3) is produced by a similar process, with the notional FEE dwelling (simulation 4) combining the two sets of standardisations.

Please see the FHS consultation for the proposed notional dwelling and FEE dwelling specifications. These specifications are being consulted on as part of the Future Homes Standard consultation. Note that more than one notional dwelling specification is being considered in the consultation.

5.1.2 Emission Rate and Primary Energy Rate

The Home Energy Model: FHS assessment evaluates the emission rates and primary energy rates of the actual and notional dwellings (simulations 1 & 2 in Table 7) by:

1. Simulating and recording the dwelling's energy performance over the year.
2. Isolating the "regulated" energy consumption (covering space heating, space cooling, hot water, ventilation, fans and pumps, and fixed lighting) by fuel type. The total electricity generated on site is also calculated.[6]
3. Multiplying this consumption and generation by either:
    a. The fuel's emission factor (for the DER/TER); or
    b. The fuel's primary energy factor (for the DPER/TPER); and
4. Dividing by floor area to give the final metric.

This can be represented by the following equation:

$$\frac{\sum_{fuels}(regulated\ fuel\ consumption \times fuel\ factor)\ - (electricity\ generation \times electricity\ factor)}{floor\ area}$$

[6] The metrics account for the total amount of electricity generated on-site, whether this generation offset regulated consumption, other consumption, or was exported. This generation is assigned the appropriate fuel factors and is then subtracted from the total emissions and primary energy due to regulated consumption (i.e. generation is rewarded by the metrics). See section 5.2.3 for further information.

5.1.3 Fabric Energy Efficiency

The Home Energy Model: FHS assessment evaluates the fabric energy efficiency of the FEE dwelling and notional FEE dwelling (simulations 3 & 4 in Table 7) by:

1. Simulating and recording the dwelling's total space heating demand over the year.
2. Simulating and recording the dwelling's total space cooling demand over the year.
3. Adding these two demands together.
4. Dividing by floor area to give the final metric.

This can be represented by the following equation:

$$\frac{total\ space\ heating\ demand + total\ space\ cooling\ demand}{floor\ area}$$

5.1.4 Additional outputs

The consultation tool outputs some additional outputs for the actual dwelling, including the dwelling's:

- annual space heating demand (kWh/m^2)
- annual space cooling demand (kWh/m^2)
- annual energy use
    - total energy use (kWh/m^2)
    - energy use by use type (e.g. water heating, ventilation, lighting) (kWh/m^2)
    - energy use by fuel type (e.g. mains electricity, mains gas) (kWh/m^2)
- heat transfer coefficient (W/K and W/m^2.K)
- annual on-site electricity generation
    - exported (kWh)
    - used on-site (kWh)
- peak half-hour electricity draw (kWh)

The consultation tool also produces detailed results files which are available for download (including results for each half-hour of the year).

The metrics listed above do not form part of the FHS assessment; however, they provide some examples of the outputs that can be produced by the Home Energy Model. Different wrappers will be able to define different outputs bespoke to their purpose (see section 3.5 in the Home Energy Model consultation).

22. What are your views on the additional metrics produced by the FHS assessment wrapper (i.e. metrics produced in addition to the FHS compliance metrics)? Please provide your reasoning and any supporting evidence.

23. What are your suggestions for additional metrics (i.e. metrics produced in addition to the FHS compliance metrics) not currently produced by the FHS assessment wrapper? Please make suggestions, explaining your reasoning, and providing any supporting evidence.

5.2 Fuel assumptions (emissions and primary energy)

Technical Paper: HEMFHS-TP-05 FHS fuel factors

In order to calculate the emission rate and primary energy rate (section 5.1.2), the FHS assessment wrapper applies a set of emission factors and primary energy factors to the energy consumption results from the core engine.

The full set of emission and primary energy factors for the Home Energy Model: FHS assessment (consultation version) can be found in Annex A.

Note that we are not publishing assumptions on fuel prices as part of the FHS assessment wrapper, as fuel prices are not used in the evaluation of the FHS compliance metrics.

The chosen boundary for these factors aligns with BS EN ISO 52000-1:2017, and is unchanged from SAP 10.2. The boundary begins with the extraction of raw fossil fuels, cultivation of biomass products, or capture of renewable energy sources, and ends with the use of the fuel within the dwelling. This omits the impacts of waste disposal and the construction of infrastructure to facilitate the processing of the fuels.

5.2.1 Emission factors for fuels

The majority of emissions factors are taken directly from the 2022 Government Greenhouse Gas Conversion Factors for Company Reporting[7] ("Government Conversion Factors") and include emissions of nitrous oxide and methane. This is mostly unchanged from SAP 10.2, although a few fuels have new sources:

- Mains gas: previously based on projected grid mix over 2020-2024, but now taken directly from the Government Conversion Factors.

[7] The 2023 release was published in June 2023, with further updates expected prior to implementation of the Home Energy Model: FHS assessment. We expect to update the figures accordingly, with a minor impact.

- Manufactured solid fuels: previously used a calculator value that is no longer available. Now taken directly from the Government Conversion Factors.

As in SAP 10.2, the emissions factors include Scope 1 (direct) and Scope 3 (indirect) emissions[8]. Emissions defined as "out of scope" by the Greenhouse Gas Protocol, notably CO2 emissions from combustion of biomass, have not been included when evaluating the FHS compliance metrics.

5.2.2 Primary energy factors for fuels

Primary energy factors are calculated from data provided over a range of sources, matching the source for the emissions factors where possible. Many sources are the same as those used for SAP 10.2, although the most notable change is the use of updated 2022 Digest of UK Energy Statistics (DUKES) figures[9].

24. **What are your views on the methodological approach to define the emission factors and primary energy factors used within the Home Energy Model: FHS assessment? Please provide your reasoning and any supporting evidence.**

5.2.3 Electricity

The generation mix for mains electricity is forecast to change considerably in the future as the grid decarbonises. We have therefore used a projection from the government's Dynamic Dispatch Model (DDM) to determine the emission and primary energy factors to be used for mains electricity in the FHS assessment wrapper.

The FHS assessment wrapper electricity factors are an average over the projected period 2025-2029. This range was chosen to reflect anticipated changes to the grid and reduce the risk of the factors becoming out of date. Adopting present-day factors in 2023 for regulations coming in 2025 would increase the likelihood of a significant change later in development.

The FHS assessment wrapper uses annual factors for electricity. In SAP 10.2, the annual factors received adjustments for each month of the year based on historical data on grid variability (Tables 12d and 12e in the SAP 10.2 specification). In recent years, the seasonal variation pattern in these factors has reduced to near zero (though random variation remains). Since we are using an average over multiple projected future years, this variability could not be robustly forecast and so the monthly variation has been removed. The use of annual figures also precludes varying electricity factors within each simulated day.

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[8] Scope 2 (energy indirect) emissions are treated separately when considering electricity and heat networks.
[9] The 2023 release was published in July 2023, with further updates expected prior to implementation of the Home Energy Model: FHS assessment. We expect to update the figures accordingly, with a minor impact.

We will continue to consider approaches to allow for greater variability in electricity factors than single annual figures. This is expected to be important for evaluating the benefits of load-shifting and energy storage technologies.

The emission and primary energy factors for renewable on-site electricity have also changed compared to SAP 10.2 due to a change of accounting convention and correction of an inconsistency between self-use and export.

Table 8 – Electricity emission and primary energy factors

		FHS assessment (consultation ver.)	**SAP 10.2 (Table 12)**
Mains electricity	Emission factor	0.086	0.136
	Primary energy factor	1.969	1.501
Renewable on-site electricity generation (self-use and export)	Emission factor	0.0	0.136
	Primary energy factor	1.0	0.501

Electricity assumptions

- A single average emissions factor and primary energy factor. Monthly variability assumptions used in SAP 10.2 have been removed.
- Factors derived from Dynamic Dispatch Model projection scenario for the years 2025-2029.
- Change to accounting convention when considering self-use and export of locally generated electricity.

25. What are your views on the proposed emission and primary energy factors for electricity? Please explain your reasoning and provide any supporting evidence.

5.2.4 Energy Shortfall

Unlike SAP 10.2, the Home Energy Model is able to represent the under-supply of energy, resulting in a home not reaching its setpoint temperature. This energy shortfall is reported by the Home Energy Model.

To prevent undersized heating systems being rewarded with a better DER and DPER than correctly sized systems, we have introduced an emissions factor and primary energy factor for “energy shortfall” to penalise this.

For this consultation these factors have taken placeholder values which are equal to twice the electricity factors for each metric.

26. What are your views on the penalisation of energy shortfall and the energy shortfall factors? Please provide your reasoning and any supporting evidence.

5.2.5 Heat networks, community heating, etc.

Heat networks and community heating schemes are not currently being assigned generic emissions or primary energy factors. We expect each large network to receive a specific treatment via a database (see the FHS consultation for further information).

We will consider the treatment of community schemes and other less common heat sources as part of the next phase of development.

Chapter 6: Validating the assumptions used in the FHS assessment wrapper

Validation is the process of checking how well a model meets its goals and user needs. Our intent for the Home Energy Model: FHS assessment is to provide a robust estimate of energy performance under "expected" conditions, taking account of typical occupant behaviours and other relevant circumstances in England.

These assumptions can and should be evaluated independently of one another against relevant data and evidence, different to that which was used to generate them. Some data comparisons and evidence evaluations are described in the technical documentation, and we will carry out further improvements, as noted in the preceding chapters. We encourage consultees to carry out their own evaluations and contribute to the continuous improvement of the FHS assessment wrapper.

In addition, we have assessed the Home Energy Model: FHS assessment's overall performance against comparable modelling tools and real monitoring data to examine whether these assumptions produce plausible, appropriate results for the assessment of new dwellings.

Validation of the wrapper is only possible following our validation of the underlying building physics in the Home Energy Model core engine (see Chapter 6 in the Home Energy Model consultation). This means we can isolate the wrapper assumptions and validate them independently of the core. However, as a result, the FHS assessment wrapper has undergone less validation than the core engine to date.

This chapter describes the approach taken to validate the FHS assessment wrapper and summarises the results of those validation exercises. We then seek views and suggestions to support future validation.

6.1 Validation against benchmark building energy models

Technical Paper: HEM-VAL-01 Inter-model comparison

In this validation exercise, we compared the Home Energy Model: FHS assessment against:

- The Passivhaus Planning Package (PHPP), a building energy model which is regarded as demonstrably accurate for modelling of high-performance homes in the field. PHPP is often used during new build projects in a manner analogous to SAP, including the use of standardised assumptions around occupant behaviour and exterior conditions.

- Environmental Systems Performance – Research (ESP-r), a building energy model which is known to have good building physics accuracy, and which was used extensively in the validation of the core engine. ESP-r does not provide standardised assumptions in the way that SAP and PHPP do. Therefore, the FHS assessment wrapper assumptions have been replicated as far as possible to observe their interactions with the complex dynamic simulation modelling ESP-r provides.
- SAP 10.2, to understand how and where the Home Energy Model: FHS assessment differs as a result of improvements to the standardised assumptions and underlying building physics.

Method

We ran three archetype homes through the models and compared the results. The archetypes used were[10]:

- A detached house,
- A deck access flat (mid-floor),
- A Victorian-era flat (mid-floor).

These archetypes are fictional but realistic dwellings chosen to cover a reasonable range of build types. The Victorian flat archetype was chosen to have relatively poor fabric quality, with the other archetypes specified at current new build fabric standards, to ensure relevance to the Future Homes Standard.

Phase 1 focused on simulating the building physics of the archetype homes using each of the models. To better facilitate this, conventions across the models were aligned as far as possible. See Chapter 6 in the Home Energy Model consultation.

Phase 2, summarised here, investigated the impact of default assumptions and modelling conventions on the model outputs. This was where the impact of the FHS assessment wrapper assumptions could be assessed. We did this by progressively relaxing the alignment of the models from Phase 1. Over the different stages, the models were allowed to use an increasing number of their own standardised assumptions and conventions, such as:

- Space heating setpoint temperatures
- Space heating hours
- Calculation of internal gains (e.g. from appliance use, human metabolism etc.)

The final stage represented the output for each model that would be expected in practice.

[10] Note this is a subset of the archetypes used in validation of the core engine (Phase 1). The additional archetypes (a semi-detached house and a terraced house) were consistently found to give very similar results to the detached house. Since comparison of the impact of the FHS assessment assumptions was an iterative and labour-intensive process, these additional two archetypes were omitted to save development time.

We analysed and compared the following key metrics:

- Space heating demand
- Internal temperature
- Dwelling energy consumption by end-use

Results and conclusions

The validation results show that the FHS assessment wrapper assumptions produce significant divergences from the level of alignment observed in Phase 1. The results also indicated key areas of sensitivity for the Home Energy Model: FHS assessment which have been used to guide development and refining of assumptions. Some key observations are noted below.

Large changes occurred with the introduction of standardised heating hours. This was expected, since the way that each model simulates the rate of cool down and heat loss differs. For example, the differences in thermal mass calculation and heat transfer coefficients noted in Phase 1 between ESP-r and the Home Energy Model are exacerbated by the FHS assessment wrapper's intermittent heating programme.

The comparatively high average external temperature applied by the FHS assessment's projected weather data (see Chapter 4) tended to lower space heating demands for both ESP-r and the Home Energy Model: FHS assessment relative to SAP 10.2 and PHPP.

PHPP experienced less heat loss through pipework than the Home Energy Model: FHS assessment due to its average of 6 tapping events per person per day, against an average of 11.5 calculated for the FHS assessment wrapper. As a result, the energy lost after tapping events was higher in the Home Energy Model: FHS assessment.

The half-hourly models (Home Energy Model: FHS assessment and ESP-r) unsurprisingly both predict a greater variation in internal temperatures compared to SAP 10.2 and PHPP, which use monthly averages. The variation is greater in ESP-r due to known effects explored in Phase 1. The Home Energy Model and ESP-r also tend to concentrate more of their heat demand in the winter months and away from the spring and autumn, compared to the monthly models.

One example output from Phase 2 is shown in Figure 9 below. This figure shows the annual and monthly energy demand by end use for each of the models for the detached house archetype, as well as average internal temperatures. The three assessment models (PHPP, SAP 10.2, and the Home Energy Model: FHS assessment) are configured as if they were assessing a real dwelling, according to their respective conventions and assumptions. In this run, all models are using high-capacity electric resistive heating, to ensure demand is met and facilitate comparison of overall heat demand levels.

Table 2Dc_DE Annual Energy Demand

		2Dc_DE			
		ESP-r	PHPP	SAP10.2	HEM
Annual Energy Demand (kWh/yr)	Space Heating	3,575	5,465	4,081	4,143
	Hot Water		1,027	1,255	1,483
	Cooling		0	129	0
	Lighting		72	n/a	119
	Ventilation		58	n/a	110

Table 2Dc_DE Annual Energy Use

		2Dc_DE			
		ESP-r	PHPP	SAP10.2	HEM
Annual Energy Use (kWh/yr)	Space Heating	3575.0	5464.8	4080.5	4140.4
	Hot Water		1770.8	2089.5	2569.4
	Cooling		0.0	0.0	n/a
	Lighting		72.0	189.3	119.2
	Ventilation		99.0	130.7	109.6
	Unregulated Uses		1306.2	2761.4	2217.9
	Total	3575.0	8712.7	9251.4	9156.4

Table 2Dc_DE Monthly Space Heating Demand

		2Dc_DE			
		ESP-r	PHPP	SAP10.2	HEM
Monthly Space Heating Demand (kWh)	January	773.0	1045.0	772.1	851.3
	February	601.0	819.0	606.5	710.3
	March	456.0	683.0	529.5	530.8
	April	216.0	428.0	333.1	284.1
	May	35.0	157.0	176.9	68.9
	June	3.0	15.0	0.0	4.2
	July	0.0	1.0	0.0	0.4
	August	0.0	0.0	0.0	0.0
	September	27.0	55.0	0.0	43.7
	October	191.0	412.0	309.1	228.8
	November	519.0	785.0	556.8	596.3
	December	754.0	1063.0	796.4	823.7

Table 2Dc_DE Operative and Internal Air Temperatures

		2Dc_DE			
		ESP-r	PHPP	SAP10.2	HEM
Annual Internal Air (dry bulb) Temperature [average for whole dwelling] (°C)		21.2	20.0	19.2	21.1
Half-Hourly Operative Temperature	Zone 1: Winter Week] (oC)	18.8			19.3
	Zone 2: [Winter Week] (oC)	19.2			19.6
	Zone 1: [Summer Week] (oC)	28.3			26.5
	Zone 2: [Summer Week] (oC)	28.8			26.7

Figure 9 – Example outputs comparing the Home Energy Model FHS assessment and other models for the detached house archetype, with HEM:FHS, SAP 10.2 and PHPP all running as they would in their real application.

In Figure 9, PHPP has the highest space heating demand, ESP-r the lowest, with SAP 10.2 and the Home Energy Model predicting similar levels in between the two. PHPP has a lower average setpoint than the Home Energy Model: FHS assessment (20ºC throughout the dwelling in PHPP), but assumed fully continuous heating. The intermittent heating pattern in the other models lowers the overall demand for heat, and results in lower average internal temperatures.

The Home Energy Model: FHS assessment predicts the highest annual water heating demand among the models due to a higher volume of hot water consumption. This was derived using a large and recent field study (see Section 3.3) and so is not currently considered to be an area of weakness.

The Home Energy Model: FHS assessment is shown to predict a lighting, ventilation and unregulated (appliance) annual energy demand with consistently closer alignment to PHPP than SAP 10.2. Total gains from both hot water and other electricity use are still higher than in PHPP, and these will tend to lower space heating demand.

Overall, the three assessment models present significantly distinct views of the archetype dwellings, and often do not conform to within the statistical guidelines we set. The divergence due to the differences in standardised assumptions is a major contributor to the overall differences, as the aligned Phase 1 models generally produced more similar estimates across all the models.

We note that PHPP and ESP-r, our two benchmark comparator models, generally had the greatest differences between their space heating demand, with the Home Energy Model falling in the middle in most tests.

Further testing of the variation in behaviour between different dwelling types and heating system configurations in the Home Energy Model: FHS assessment will be carried out during and following the consultation period. In particular, it is expected that the use of appropriately sized heat pump systems, in combination with set-back temperature and warm-up period configurations (see Section 3.2.2) will result in higher heat demand estimates in Home Energy Model: FHS assessments. This will be explored in the next phase of testing.

27. **What are your views on the inter-model validation work that has been carried out (i.e. against SAP 10.2, PHPP and ESP-r)? Please provide your reasoning and any supporting evidence.**

6.2 Validation against real-world case studies

We have validated the Home Energy Model against the following real-world case studies:

1. The Camden Passivhaus, designed by Bere Architects.

2. Three homes from the Marmalade Lane development in Cambridge, which were monitored during construction and used as part of the Building for 2050 research project.

Both these studies were primarily directed towards validation of the core building physics, through "calibration" of the Home Energy Model inputs to closely match the real circumstances in the dwellings during the monitoring period. However, by comparing these calibrated runs of the Home Energy Model against the "uncalibrated" (i.e. FHS assessment wrapper) starting point, some indicative sense of the impact of standardised assumptions can be given.

These results should not be viewed as representative of the typical anticipated accuracy of Home Energy Model: FHS assessments in the field. They are anecdotal and are noted here to demonstrate the impact of standardising inputs, as opposed to using the most accurate "calibrated" parameters available, when comparing to real measured energy consumption in a real dwelling. In the next phase of development we will look to undertake further comparisons of the FHS assessment wrapper assumptions against real dwellings in the form of representative population data, as opposed to individual case studies.

Camden Passivhaus

Validation Paper: HEM-VAL-03 In-use validation – Camden Passivhaus

The Camden Passivhaus is a house in London designed by Bere Architects to Passivhaus standards. Its performance has been studied in detail as part of the Technology Strategy Board (now Innovate UK) Building Performance Evaluation Programme. The house has mechanical ventilation with heat recovery, a high standard of insulation and airtightness, high performance glazing, and (apart from two heated towel rails) heating via the ventilation supply air.

The data collected covered the period from February 2012 to January 2013, during which the dwelling was occupied. Initially the Home Energy Model: FHS assessment was run normally (the uncalibrated run). To examine the sources of divergence from the measured values, the inputs were progressively adjusted to make use of the most appropriate data available for this specific dwelling.

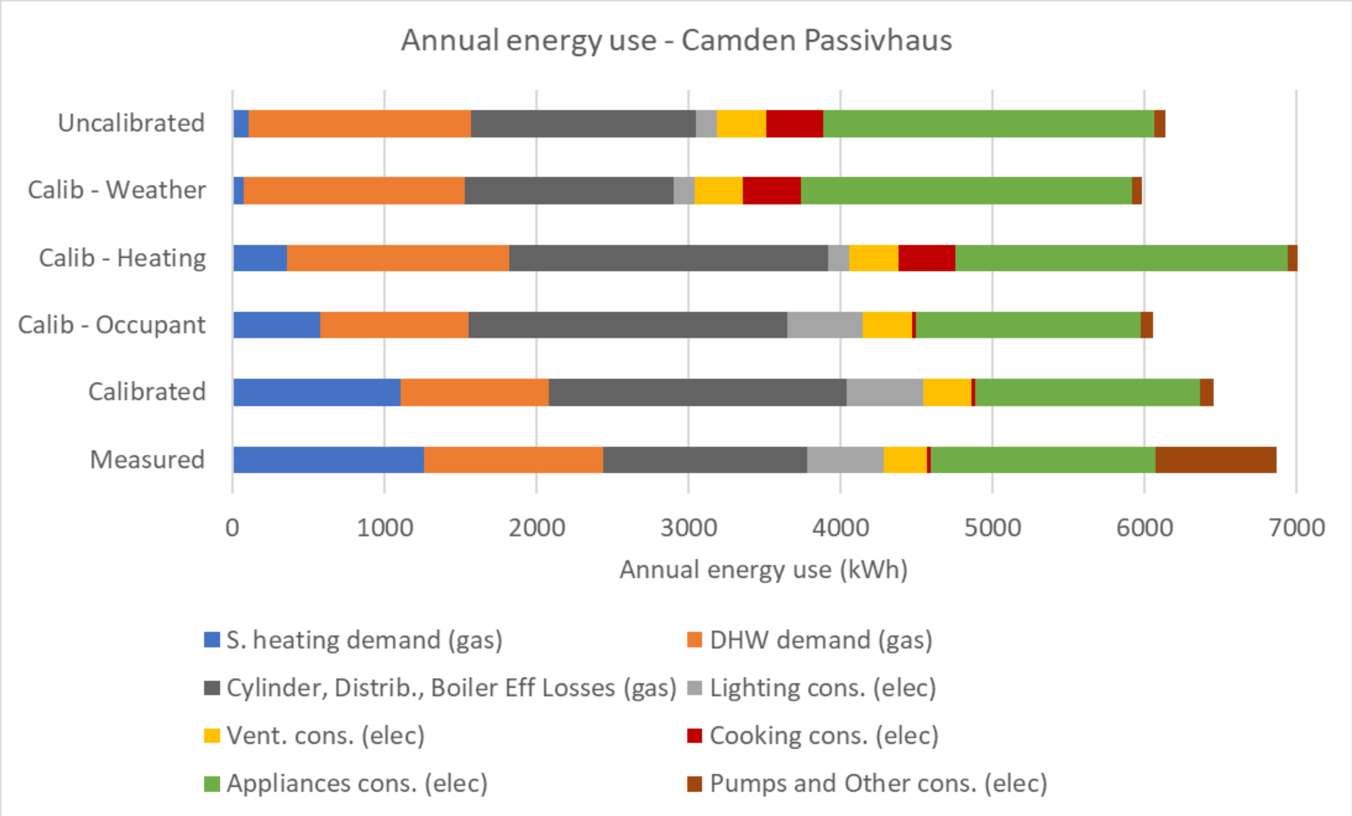

Figure 10 – Comparison of Home Energy Model: FHS assessment total annual energy consumption by end-use with measured data from the real dwelling. The model and measurements converge as input calibration is progressively added in different areas. The "Calibrated" run combines the weather, heating pattern and occupancy calibrations.

As Figure 10 shows, in this particular case the FHS assessment wrapper assumptions led to a significant underestimate of overall energy use for space heating, which the calibrations were able to largely overcome at the annual level (though greater disparities can be seen in the monthly figures).

In this high performing dwelling, the space heating demand was highly sensitive to occupant behaviours, notably internal shading of the considerable glazed area and the choice of heating regime.

Building for 2050 – Marmalade Lane development

Validation Paper: HEM-VAL-04 In-use validation – Building for 2050

The Building for 2050 project was a study of the construction of low-cost, low-carbon homes, funded by the then Department for Business, Energy & Industrial Strategy. In this validation exercise, we have used monitoring data from three homes from the project's Marmalade Lane housing development in Cambridge. These homes have air-source heat pumps and mechanical ventilation with heat recovery. Their fabric is not to Passivhaus standards but is comparable to or better than Part L 2021.

The monitoring data used was from a period in 2019-2020, when the homes were occupied. In order to compare the monitored data to the Home Energy Model, we calibrated the weather, occupancy, and space heating regime assumptions in the two models, so that they better represented the actual conditions.

In this case study SAP 10.2 runs (both calibrated and uncalibrated) were carried out alongside the Home Energy Model runs.

A major uncertainty is the limited data available on the behaviour of the residents. Other uncertainties include the accuracy of the input data entered into the model, such as whether the data entered on the building fabric and building services performance accurately represented the actual performance, and the accuracy of the measured data itself. It was also not possible to separate energy use by different end uses; notably space heating and hot water consumption could not be distinguished and so the split was estimated.

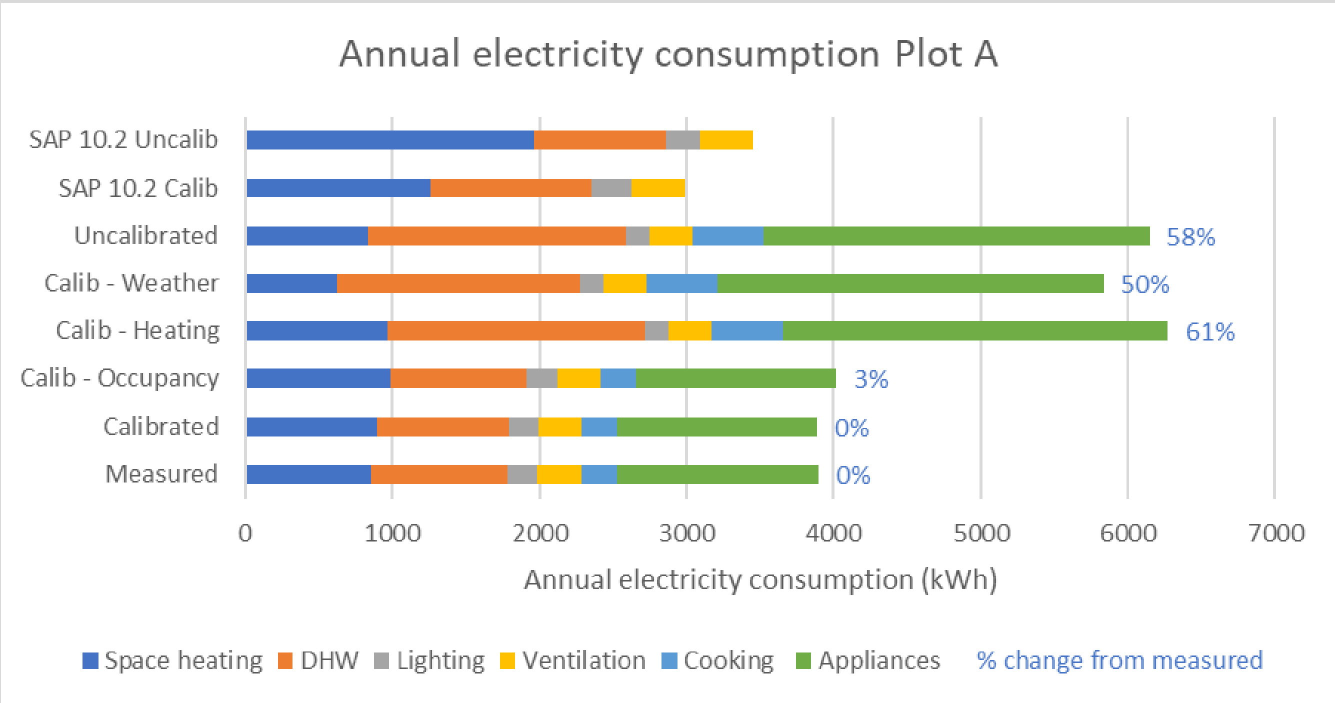

Figure 11 – Comparison of SAP 10.2 and Home Energy Model estimated annual electricity consumption, by end-use, compared with the measured consumption (with an estimated split by end-use) for one of the Marmalade Lane dwellings.

The pattern seen in Figure 11 for Plot A of the Marmalade Lane development was consistent across the three plots used in the validation testing (see the accompanying technical report for the full results). Note the SAP 10.2 output did not consider the cooking or appliance consumption and so this is not shown.

The level of agreement observed between the Home Energy Model and the measured data (both before and after calibration of the inputs) should be viewed with caution. However, since common calibration was used between Home Energy Model and SAP 10.2 as far as possible, the conclusion that Home Energy Model: FHS assessment has better reflected these dwellings compared to SAP 10.2 would appear to be comparatively robust.

28. **What are your views on the monitoring data case study validation work that has been carried out? Please explain your reasoning and provide any supporting evidence.**

6.3 Future validation

The Home Energy Model: FHS assessment is still under development and will ‘go live’ alongside the Future Homes Standard in 2025. In advance of this, we will undertake further validation of the assumptions in the FHS assessment wrapper, to ensure they are as robust as possible. This will likely include:

- Further validation of the Home Energy Model: FHS assessment against more representative data from real dwellings.
- Additional analysis of unregulated energy use, such as using bottom-up calculations to validate the profiles created from national survey data.
- Comparison of different heating systems and heating schedules to further explore the performance of these under the FHS assessment assumptions.

29. **What suggestions do you have for further validation exercises that could be undertaken to refine the Home Energy Model: FHS assessment? Please make suggestions, explaining your reasoning, and providing any supporting evidence.**

Public Sector Equality Duty

The government must consider how policies and decisions affect people who are protected under the Equality Act 2010. The protected characteristics: age; disability; gender reassignment; marriage or civil partnership; pregnancy and maternity; race; religion or belief; sex; and sexual orientation.

The Home Energy Model: FHS assessment includes assumptions around occupancy and occupant behaviour in order to create a standardised assessment procedure for all new homes. These assumptions have been based on international modelling standards and on survey data from large samples of households (e.g. the English Housing Survey, Connected Devices study), and therefore represented historic population averages. See Chapter 3 and the accompanying technical documentation for further information on the evidence base behind the model assumptions.

We intend to undertake an equality assessment of these assumptions and their evidence base in advance of implementation and will make any necessary refinements to the model as a result. This will be supported by further model validation using a wider variety of home archetypes (see Chapter 6).

30. **What are your views on the equality considerations of these assumptions and their evidence base? Please provide your reasoning and any supporting evidence.**

Environmental Principles Policy Statement

The Environment Act 2021 places a duty on the government to consider the environmental principles policy statement (EPPS) when making policy, to help protect and enhance the environment whilst supporting innovation and economic growth. The statement sets out how to interpret and proportionately apply the five environmental principles:

1. The integration principle – policy-makers should look for opportunities to embed environmental protection in other fields of policy that have impacts of the environment
2. The prevention principle – government policy should aim to prevent environmental harm
3. The rectification at source – if damage to the environment cannot be prevented it should be tackled at its origin
4. The polluter pays principle – those who cause pollution or damage to the environment should be responsible for mitigation or compensation
5. The precautionary principle – where there are threats of serious or irreversible damage, a lack of full scientific certainty shall not be used a reason for postponing cost-effective measures to prevent environmental degradation

The Home Energy Model: FHS assessment is a calculation methodology designed to assess a dwelling's compliance with the FHS. The model will therefore have an indirect impact on the environment by enabling the implementation of the Future Homes Standard. For example, the Home Energy Model: FHS assessment will support a reduction in the CO2 emissions produced by new homes.

The Home Energy Model: FHS assessment estimates the emissions and energy consumed by a dwelling under certain conditions, and therefore includes assumptions around the weather and the emissions/primary energy of different fuels. These assumptions are based on the latest government statistics and environmental reporting. See Chapters 4 and 5 for further information.

We have undertaken a series of validation exercises to ensure the model provides a robust estimate of energy performance under "expected" conditions (see Chapter 6)

We will consider the possible environmental impacts of the Home Energy Model: FHS assessment during the next phase of development.

31. **What are your views on the possible environmental impacts of the Home Energy Model: FHS assessment itself? Please provide your reasoning and any supporting evidence.**

Next steps

This consultation presents the Home Energy Model: Future Homes Standard assessment, which will be used to demonstrate new homes' compliance with the Future Homes Standard.

The Home Energy Model: FHS assessment is still under development and will be refined prior to being implemented alongside the FHS in 2025. Responses to this consultation will provide valuable feedback and recommendations for further development in advance of its introduction.

In 2022, the government appointed a consortium led by Etude[11] to quality assure the Home Energy Model throughout its development. For this publication, Etude have produced an evaluation of the consultation version of the Home Energy Model: FHS assessment against key success criteria (see the evaluation report on the Home Energy Model consultation page). This evaluation, alongside the responses to this consultation, will be used to plan the next phase of development.

Following a period of further development and validation, we will publish a Government Response to this consultation alongside a response to the Future Homes Standard consultation in 2024. This response will confirm the assumptions that are to be used in the Home Energy Model: FHS assessment.

[11] Project team: Levitt Bernstein, UCL, Julie Godefroy Sustainability, and Etude.

Consultation questions

Chapter 2: The Future Homes Standard assessment: a wrapper for the Home Energy Model

1. What are your views on the choice of inputs that have been standardised vs left open as user inputs (as in the consultation tool)? Please explain your reasoning and provide any supporting evidence.

2. What are your views on the ease of populating or sourcing data for those user inputs? Please explain your reasoning and provide any supporting evidence.

Chapter 3: Occupancy and energy demand

Occupancy assumptions

3. What are your views on the proposed standard occupancy assumption? Please explain your reasoning and provide any supporting evidence.

4. What are your views on the assumptions for metabolic gains? Please explain your reasoning and provide any supporting evidence.

Space heating and cooling assumptions

5. Do you think the FHS assessment wrapper should keep two thermal zones for all dwellings? Y/N. Please provide your reasoning and any supporting evidence.

6. If the FHS assessment wrapper keeps two thermal zones, do you think we should introduce inter-zone heat transfer? Y/N. Please provide your reasoning and any supporting evidence.

7. What are your views on heating setpoints for (a) one zone; (b) two zones without inter-zone heat transfer (i.e. the current assumptions given above); and (c) two zones with inter-zone heat transfer? Please provide reasoning and supporting evidence.

8. What are your views on the assumptions for space heating hours? Please provide your reasoning and any supporting evidence.

9. What are your views on the ability to specify a control scheme (e.g. setback temperatures and "advanced start" periods) that works for the system being installed? Please provide your reasoning and any supporting evidence.

10. What are your views on the treatment of the heating season vs non-heating season (months where the heating is assumed to be off regardless of the temperature)? Please provide your reasoning and any supporting evidence.

11. What are your views on the proposed assumptions for the use of space cooling systems? Please provide your reasoning and any supporting evidence.

Domestic hot water assumptions

12. What are your views on the assumptions for the volume of hot water demand? Please provide your reasoning and any supporting evidence.
13. What are your views on the pseudo-randomly generated hot water use schedule, including the algorithm generating it? Please provide your reasoning and any supporting evidence.
14. What are your views on the proposed hot water / mixed water temperature assumptions? Please provide your reasoning and any supporting evidence.
15. What are your views on the assumptions for water heating hours? Please provide your reasoning and any supporting evidence.
16. What are your views on the cold water feed temperature assumptions? Please provide your reasoning and any supporting evidence.

Lighting, cooking, and appliances assumptions

17. What are your views on the proposed assumptions for lighting demand, time of use, and thermal gains availability? Please provide your reasoning and any supporting evidence.
18. What are your views on the proposed assumptions for cooking energy demand, time of use, and thermal gains availability? Please provide your reasoning and any supporting evidence.
19. What are your views on the assumptions for appliance energy demand, time of use, and thermal gains availability? Please provide your reasoning and any supporting evidence.
20. What are your views on the assumptions for cold water and evaporative losses? Please provide your reasoning and any supporting evidence.

Chapter 4: Weather assumptions

21. What are your views on the use of climate projections rather than historical averages for the weather assumptions within the model? Please provide your reasoning and any supporting evidence.

Chapter 5: FHS compliance metrics

Metrics

22. What are your views on the additional metrics produced by the FHS assessment wrapper (i.e. metrics produced in addition to the FHS compliance metrics)? Please provide your reasoning and any supporting evidence.
23. What are your suggestions for additional metrics (i.e. metrics produced in addition to the FHS compliance metrics) not currently produced by the FHS assessment wrapper?

Please make suggestions, explaining your reasoning, and providing any supporting evidence.

Fuel assumptions (emissions and primary energy)

24. What are your views on the methodological approach to define the emission factors and primary energy factors used within the Home Energy Model: FHS assessment? Please provide your reasoning and any supporting evidence.

25. What are your views on the proposed emission and primary energy factors for electricity? Please explain your reasoning and provide any supporting evidence.

26. What are your views on the penalisation of energy shortfall and the energy shortfall factors? Please provide your reasoning and any supporting evidence.

Chapter 6: Validating the assumptions used in the FHS assessment wrapper

27. What are your views on the inter-model validation work that has been carried out (i.e. against SAP 10.2, PHPP and ESP-r)? Please provide your reasoning and any supporting evidence.

28. What are your views on the monitoring data case study validation work that has been carried out? Please explain your reasoning and provide any supporting evidence.

29. What suggestions do you have for further validation exercises that could be undertaken to refine the Home Energy Model: FHS assessment? Please make suggestions, explaining your reasoning, and providing any supporting evidence.

Public Sector Equality Duty

30. What are your views on the equality considerations of these assumptions and their evidence base? Please provide your reasoning and any supporting evidence.

Environmental Principles Policy Statement

31. What are your views on the possible environmental impacts of the Home Energy Model: FHS assessment itself? Please provide your reasoning and any supporting evidence.

Annex A – Emission factors and primary energy factors

The emission factors and primary energy factors for the Home Energy Model: FHS assessment (consultation version) are given in the table below.

Note that not all of these fuels are available to test in the consultation tool, as the corresponding technologies have not yet been fully implemented.

Fuel type	**Emission factor (kgCO2e/kWh)**	**Primary energy factor (kWh_{PE}/kWh)**
Mains electricity	0.086	1.969
Renewable on-site electricity generation (for self-use or export)	0.0	1.0
Mains gas	0.214	1.120
LPG (all types)	0.240	1.104
Heating oil	0.298	1.136
House coal (including anthracite and manufactured)	0.398	1.094
Biogas (including anaerobic digestion)	0.029	1.442
Bio-liquid HVO from used cooking oil	0.041	1.010
Bio-liquid FAME from animal/vegetable oils	0.058	1.152
B30K	0.226	1.141
Bioethanol from any biomass source	0.072	1.348
Wood logs	0.023	1.065
Wood pellets	0.048	1.306
Wood chips	0.018	1.069
Energy shortfall	0.172	3.938

This consultation is available from: Home Energy Model: Future Homes Standard assessment